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FISCAL YEAR 1989
DEPARTMENT OF ENERGY
AUTHORIZATION

(Fossil Energy R&D and Clean Coal Technology Program)

HEARINGS

BEFORE THE

SUBCOMMITTEE ON
ENERGY RESEARCH AND DEVELOPMENT

OF THE

COMMITTEE ON
SCIENCE, SPACE, AND TECHNOLOGY
HOUSE OF REPRESENTATIVES

ONE HUNDREDTH CONGRESS

SECOND SESSION

MARCH 2, 3, 1988

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CONTENTS

WITNESSES

March 2, 1988:

Page

- Opening statement of Hon. Marilyn Lloyd, Chairman, Subcommittee on Energy Research and Development 1
- Opening statement of Hon. Sid Morrison, Ranking Republican Member, Subcommittee on Energy Research and Development 3
- Hon. J. Allen Wampler, Assistant Secretary for Fossil Energy, U.S. Department of Energy, Washington, DC; accompanied by Donald L. Bauer, Principal Deputy Assistant Secretary for Fossil Energy; Jeremiah E. Walsh, Jr., Deputy Assistant Secretary for Management, Fundamental Research and Cooperative Development; and Jack S. Siegel, Deputy Assistant Secretary for Coal Technology 4
  - Prepared statement 8
  - Discussion 38
  - Questions and answers for the record 48

PANEL: PRIVATE SECTOR

- Ben Yamagata, Executive Director, Clean Coal Technology Coalition, Washington, DC 232
  - Prepared statement 235
- Dr. Kurt E. Yeager, Vice President and Director, Coal Combustion Systems Division, Electric Power Research Institute, Palo Alto, CA 245
  - Prepared statement 248
- Panel discussion 267
- Questions and answers for the record:
  - Mr. Yamagata 274
  - Dr. Yeager 277

March 3, 1988:

- Opening statement of Hon. Rick Boucher, the U.S. Representative in Congress from the Ninth District in Virginia 283
- Opening statement of Hon. Sid Morrison, Ranking Republican Member, Subcommittee on Energy Research and Development 284

PANEL 1: FUEL CELLS

- Martin Gutstein, Executive Director, Fuel Cell Association, Washington, DC 284
  - Prepared statement 287
- Dr. Frank C. Shora, President, M-C Power Corporation, Chicago, IL 292
  - Prepared statement 294
- Nathaniel D. Woodson, General Manager, Energy Systems Technology Divisions, Westinghouse Electric Corporation, Pittsburgh, PA 296
  - Prepared statement 298
- Panel 1 discussion 308
- Questions and answers for the record:
  - Mr. Gutstein 313
  - Dr. Schora 316
  - Mr. Woodson 318

PANEL 2: COAL R&D

- Vincent J. Coates, Jr., Vice President, MHD Industrial Forum, Washington, DC 323
  - Prepared statement 325

March 3, 1988—Continued | Page
Dr. Danny L. Hartley, Vice President, Energy Programs, Sandia National Laboratories, Albuquerque, NM 335
Prepared statement 337
Dr. Lawrence I. Wisdom, Executive Vice President, Hydrocarbon Research, Inc., Lawrenceville, NJ 344
Prepared statement 346
Dr. Thomas G. Squires, Executive Director, Associated Western Universities, and Chairman, Fuel Chemistry Division, American Chemical Society, Washington, DC, on behalf of the American Chemical Society 360
Prepared statement 362
Panel 2 discussion 367
Questions and answers for the record:
Mr. Coates 376
Dr. Hartley 380
Dr. Wisdom 387
Dr. Squires 388

PANEL 3: PETROLEUM R&D

Opening statement of Hon. Lamar S. Smith, the U.S. Representative in Congress from the Twenty-First District in Texas 389
Dr. William L. Fisher, Director, Bureau of Economic Geology and Chairman, Department of Geological Sciences, The University of Texas at Austin, Austin, TX 390
Prepared statement 393
Dr. Raymond C. Rex, Jr., Manager of Research and Engineering, HY-CRUDE Corporation, Chicago, IL 402
Prepared statement 450
Dr. J. Read Holland, Director, The School of Mines and Energy Development, The University of Alabama, Tuscaloosa, AL 410
Prepared statement 412
Dr. M. Ray Thomasson, Executive Vice President of Exploration and Production, Pendelton Land and Exploration, Inc., Englewood, CO 415
Prepared statement 417
Panel 3 discussion 421
Questions and answers for the record:
Dr. Fisher 427
Dr. Rex 434

PANEL 4: GAS R&D

Michael Baly III, Vice President, Government Relations, American Gas Association, Arlington, VA 435
Prepared statement 437
David O. Webb, Senior Vice President, Policy and Regulatory Affairs, Gas Research Institute, Washington, DC 454
Prepared statement 456
Dr. Bernard S. Lee, President, Institute of Gas Technology, Chicago, IL 480
Prepared statement 483
Dr. Vernon T. Jones, President, The Williams Companies; and Chairman, Interstate Natural Gas Association of America, Washington, DC 494
Prepared statement 496
Panel 4 discussion 507
Questions and answers for the record:
Mr. Webb 514
Dr. Lee 519
Dr. Jones 526

APPENDIX 1: ADDITIONAL STATEMENTS FOR THE RECORD

Dr. Y.C.L. Susan Wu, Professor, Energy Conversion R&D Programs, The University of Tennessee Space Institute, Tullahoma, TN 533
Dr. B.R. Arora, Chairman, Edison Electric Institute MHD Task Force, Washington, DC 537

Page

March 3, 1988—Continued
  American Public Power Association, Washington, DC 539
  Dr. Charles H. Goodman, Vice President, Research and Environmental Affairs; and Gary A. Stiles, Project Manager, Coal Liquefaction Technology, Southern Company Services, Inc., Birmingham, AL 554

APPENDIX 2: ADDITIONAL MATERIAL FOR THE RECORD

"MHD Program Plan: FY 1988," U.S. Department of Energy, Assistant Secretary for Fossil Energy, Deputy Assistant Secretary for Oil, Gas, Shale and Special Technologies, April, 1988, DOE/FE-0104 561

1989 DEPARTMENT OF ENERGY AUTHORIZATION

WEDNESDAY, MARCH 2, 1988

House of Representatives,
Committee on Science, Space, and Technology,
Subcommittee on Energy Research and Development,
Washington, DC.

The Subcommittee met, pursuant to call, at 9:30 a.m., in room 2381, Rayburn House Office Building, Hon. Marilyn Lloyd [Chairman of the Subcommittee] presiding.

OPENING STATEMENT OF HON. MARILYN LLOYD, CHAIRMAN, SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT

Mrs. Lloyd. Good morning, ladies and gentlemen. The Subcommittee on Energy Research and Development will come to order.

I want to welcome all of you to the first hearing of the second session of the 100th Congress on energy research and development programs. I am pleased to be back here this morning. I want to welcome all of our Subcommittee Members back; only one is here so far, but surely they will be here soon. Our Subcommittee's new Members this year are Mr. Kanjorski, a Democrat from Pennsylvania; Mr. Hochbrueckner, a Democrat from New York; and Mr. Shays, a Republican from Connecticut.

I am looking forward to a vigorous pursuit of energy R&D issues in this session, but I have no illusions about the budget, and I'm sure you don't either. The DOE budget falls short of what we need in non-nuclear technology development, nuclear R&D is underfunded, and certain basic science projects are not receiving anything like good faith support from the Administration.

I believe we are facing some very tough choices, and the Subcommittee's decisions on priorities for energy technology and DOE's general and basic energy science programs will be critical. We must view today's programs in that challenging framework for decisionmaking.

Our hearing today focuses on the Department of Energy's fiscal year 1989 budget request for Fossil R&D and the Clean Coal Technology Demonstration Program. A brief recap of the budget shows that the request of $167 million for fiscal year 1989 is less than half of this year's appropriated $354 million. The coal programs are decreased by 56 percent with MHD, fuel cells, and underground coal gasification suffering the most severe reductions. At a reduction of 31 percent, the petroleum request has also been hard hit while the oil shale subprogram is reduced by a whopping 89 percent for fiscal year 1988 levels, clearly indicating that this work is a low priority within the Administration. Finally, endorsement of the gas budget request with a cut of 84 percent would ensure that the work on unconventional gas recovery would be virtually over.

This budget request follows a pattern which, in recent years, has resulted in significant congressional reordering of the Administration's spending priorities. The DOE has again submitted a drastically reduced budget under the auspices of budget deficit concerns. We in the Congress are concerned about budget deficits, but we are also concerned about maintaining U.S. capabilities in international competition and supporting our technical expertise at a level which will allow some program continuity. We are also concerned about deriving significant benefits from previous Federal investment.

I believe that to endorse the budget request as submitted would be a serious misjudgment in our efforts to support a reasonable level of energy research and technology development even in times of serious budget problems. However, I am open to well thought out suggestions as to areas where we might save some money without impacting quality R&D.

My criticisms of the budget process are not meant to detract from the accomplishments of the Department in implementing the Clean Coal Program. Progress has been made since our hearing last year. As an example of the Department's commitment to the program, they sought and they won advanced appropriations of $525 million to ensure adequate funding availability when projects are selected for Phase 2 of the program. The Program Opportunity Notice, or PON, for Phase 2, the Innovative Clean Coal Program that emphasizes technologies capable of retrofitting or repowering, has been released with a closing date of May 23, 1988. Meanwhile, the CCT initiative has progressed to the point that seven of the original nine selectees have reached agreement with the Department and four other hopefuls are currently in negotiations.

In their fiscal year 1989 budget request, the Department asked for $9 million for a Cooperative Ventures Program. The initial focus of the program will be on oil and gas technologies which will improve the identification and the characterization of the oil and gas reservoirs. This cost-shared program will assist segments of our energy business which have suffered from oil price disruptions. While our Subcommittee will be looking at this program in detail, it appears to be an appropriate assist to the oil and gas industry.

I'm very pleased to welcome back to our hearing Allen Wampler, the Assistant Secretary for Fossil Energy at the Department of Energy. Since his appointment as Assistant Secretary, Allen has certainly proven himself to be an able spokesman and an aggressive advocate for the Fossil Program. He has shown a personal commitment to research and technology development that we have not seen at this Department since the 1970's.

We certainly appreciate you, Allen.

Then, after Assistant Secretary Wampler finishes, we will hear from representatives from the Clean Coal Technology Coalition and the Electric Power Research Institute. Both witnesses will discuss the Clean Coal Program and will provide us with their insights as to the status and the prospects for the program.

But before Allen begins, I would like to recognize my friend and colleague, Sid Morrison, our Ranking Republican Member, for his opening statement.

Good morning.

OPENING STATEMENT OF HON. SID MORRISON, RANKING REPUBLICAN, SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT

Mr. MORRISON. Thank you, Madam Chairman. I am delighted as we start this next go-round on the budget process. For me, that is always an education in itself. As this Subcommittee expands its areas of jurisdiction I think we, all of us on the Subcommittee, find these hearings to be very informative. I'd like to join our good Chairman in welcoming the team and look forward to all the testimony.

I've been impressed with the diversity of Fossil Energy Program. Various research and development activities can help establish the technology base for coal to replace oil and gas in industrial, commercial, residential, transportation, and many other applications if clean coal technology can be successfully developed at the same time.

We have seen some significant accomplishments in the last couple of years and are especially pleased with the fact that there is so much involvement of the private sector, both ongoing and forthcoming, to share the technology as well as cost for the development and demonstration of new concepts in the Fossil Energy Program.

I sense some mixed emotions on the part of our Chairman, and I share those mixed feelings, about the budget proposed by DOE for fiscal year 1989. On the one hand, I am certainly delighted that in some important areas the budget continues to show a moderate increase, particularly in acid rain control, for coal as an alternative fuel, advanced concepts for coal combustion systems and waste management.

On the other hand, I am concerned about the substantial cuts in budget requests for areas such as clean coal preparation—that is a 38 percent reduction—and coal conversion including gasification and liquefaction—that is a 73 percent reduction—and the termination of programs such as the coal-fired MHD.

I recognize that one reason is the completion of some projects. However, the other reasons are that the Department thinks either the projects are too expensive to conduct or the technology is ready to be transferred to the private sector, and I am anxious to hear more details about these reasons and how we can still maintain R&D capabilities if we cut the funding of these projects.

I personally am a supporter of clean coal and look forward to the successful negotiation of the remaining four contracts for the Clean Coal Technology Program this year.

Another major effort, the Innovative Clean Coal Technology Program, will take a step forward in fiscal year 1989 to prepare for future demonstration of innovative technologies that can be commercialized in this next decade. I am pleased to see that the Department is on track with this activity and look forward to the selection of proposed projects in December and look forward to the testimony from, I think, a stellar team in this area.

Thank you, Madam Chairman.

Mrs. LLOYD. Thank you very much, Mr. Morrison.

Allen, would you like to introduce your associates that are with you today?

STATEMENT OF HON. J. ALLEN WAMPLER, ASSISTANT SECRETARY FOR FOSSIL ENERGY, U.S. DEPARTMENT OF ENERGY, WASHINGTON, DC; ACCOMPANIED BY DONALD L. BAUER, PRINCIPAL DEPUTY ASSISTANT SECRETARY FOR FOSSIL ENERGY; JEREMIAH WALSH, JR., DEPUTY ASSISTANT SECRETARY FOR MANAGEMENT, FUNDAMENTAL RESEARCH AND COOPERATIVE DEVELOPMENT; AND JACK S. SIEGEL, DEPUTY ASSISTANT SECRETARY FOR COAL TECHNOLOGY

Mr. WAMPLER. Thank you, Madam Chairman and Members of the Subcommittee.

To my immediate left is Mr. Don Bauer, who is my Principal Deputy Assistant Secretary; to his left is Mr. Jack Siegel, who is the Deputy Assistant Secretary for Coal Technology; to my right is Mr. Jerry Walsh, who is Deputy Assistant Secretary for Management, Fundamental Research and Cooperative Development.

Mrs. LLOYD. Thank you very much. We're happy to have you gentlemen with us as well today. Please proceed.

Mr. WAMPLER. Thank you, Madam Chairman and Members of the Subcommittee. It's again a pleasure to begin the fiscal year 1989 budget review process by appearing before the Subcommittee.

In addition to the staff members that I just introduced, there are several other key staff members present, and, with the Subcommittee's permission, I may ask them to assist me in answering some of your more detailed technical questions.

I would also appreciate the Subcommittee's consideration in including my formal statement in the record and permitting me to summarize.

Mrs. LLOYD. Without objection, your entire statement will be made a part of the record.

Mr. WAMPLER. Thank you.

The budget that we have submitted to you is one that we believe is necessarily aggressive in those areas where more near-term emphasis is warranted, such as in the demonstration of clean coal technologies, as the centerpiece of the Administration's response to concerns over acid rain, and in the area of enhanced oil recovery, where we have undertaken several new initiatives and have proposed a fiscal year 1989 level that is significantly larger than previous requests.

Our proposed budget is also technically sound. It emphasizes those areas where we continue to build a solid base of scientific and technical expertise in areas such as coal, oil, and gas-related research and development.

Equally important, Madam Chairman, it's an affordable budget. The items contained in our request have been balanced against a host of pressing and often competing priorities. Admittedly, there is a wealth of project ideas and concepts that could be legitimate and worthwhile candidates for Federal funding. We have subjected these ideas and concepts to a very rigorous screening process, first at the Assistant Secretary level, then at the Secretarial level, and ultimately at the Administration level.

Those that have emerged and which are contained in this budget proposal represent those that we believe are of the highest priority to the continued advance of fossil fuel technology. They are the programs and projects, we believe, that will help move the technology of coal, oil, and gas into the twenty-first century.

As I have outlined in my formal statement, our budget request is made up of two major components, the Clean Coal Technology Initiative and the Fossil Energy Research and Development Program. The two are complementary but have distinctively different orientations.

As the Subcommittee is aware, the Clean Coal Program is intended to provide Federal matching funds to demonstrate the commercial viability of a new generation of environmentally-improved, high-efficiency coal technologies. The outcome of this program will be a new suite of coal combustion and pollution control facilities that will be unmatched by any nation in the world, each project providing the performance data and the operational experience necessary for the private sector to make future deployment decisions.

The Clean Coal Program is now well under way, and it is an effort in which both the Congress and the Administration can take justifiable pride. The President's initiative incorporates a portion of, and builds on to, an ongoing $400 million effort approved by Congress in fiscal year 1986. The budget for this program in fiscal year 1988 and 1989 is $575 million. That is an amount that reflects last year's congressional approval of the first increment of the President's $2.5 billion, 5-year initiative.

As the chart on page 1 of my formal statement shows, $536 million of these funds have been made available for project financing. On February 22, the Department issued its second solicitation for clean coal technology projects. Proposals are due on May 23, and we expect to select projects by late summer.

A second aspect of our Clean Coal budget proposal is our request for advance appropriations for the remaining $1.78 billion to complete the President's initiative. As the Subcommittee is aware, the amount approved by Congress last year fell short of the President's request for the first two years of the expanded Clean Coal Program.

We remain committed to the full scope of the Clean Coal Program and, consequently, are requesting that Congress restore full funding for the program by appropriating, in advance, $575 million for fiscal year 1990, $600 million for fiscal year 1991, and $600 million for fiscal year 1992.

Advanced appropriations are important for two principal reasons: One, it is important for the U.S. to demonstrate its commitment to the full implementation of the Special Envoy's Report on Acid Rain. This is necessary both in our international relations and in assuring domestic firms that the Government is prepared to stand behind its commitment to cost sharing.

Second, it is important from an R&D perspective. Several promising Clean Coal concepts are now in the R&D pipeline. Many are not sufficiently mature to compete for Clean Coal funds today, but they could be considered as candidates within the next two to three years. For their development to continue today with as much private financing as possible, sponsors need to have confidence that the Federal commitment and the necessary cost-sharing funds will be available to take the final step at the end of the development phase. Funding for the Clean Coal Program, therefore, serves as a stimulus for continued private R&D today.

The Clean Coal Program is certainly one of the most visible parts of our Fossil Energy Program, but it should not overshadow the second component of our budget, and that is the core R&D effort. The $168 million that we are proposing for coal, oil, and natural gas research and development is a 53 percent reduction from the amount appropriated in fiscal year 1988. But in many ways, Madam Chairman, that number is misleading. Fully one half of the proposed reduction can be attributed to the phase-out of four projects that have achieved their objectives: These are the Wilsonville and LaPorte liquefaction projects, the Waltz Mill gasifier facility, and the Phosphoric Acid Fuel Cell Program, and our recommendation to cease funding for the MHD Program.

In the case of the completed projects, these are efforts that have returned important dividends in terms of new knowledge and information, but they have achieved their goals, the data is available to the private sector, and, with other pressing priorities, it is difficult to justify their continued funding.

The MHD Program is somewhat different. Here, the question is one of affordability. As we attempt to gain maximum benefit from a limited number of dollars, it is unreasonable, in our opinion, to allocate $1 out of every $10 to a single, very long-range concept. Moreover, as my formal statement indicates, the MHD Program will likely cost as much as $172 million to prove the technical concept within the next five years. We believe these funds could be better spent.

Instead of concentrating on the reduction in funding, I think it is important to also look at the 1989 budget request in context with our request of last year. By this comparison, our budget would increase by $17 million, six of nine major categories in the Coal Program would increase in funding, the Enhanced Oil Recovery Program would increase by more than 75 percent, and we have substantially boosted our request for geosciences research.

In other words, Madam Chairman, we have arrived at a budget recommendation that strengthens those areas that need strengthening and de-emphasizes those areas where goals have been achieved and targets met.

I hope that, in our discussion this morning, we can present a convincing case that this budget is technically prudent and fiscally sound. We hope to show that we have done our homework in areas such as Cooperative R&D Ventures, where we have refined our proposal based largely on the input from public meetings and from congressional guidance; we hope to demonstrate that our budget represents a balanced effort, with emphasis given not only to coal but to oil and gas; and we hope to show that this budget will be effective in continuing the significant advances that have been made in fossil energy technology in the last several years.

That completes my opening summary, and I'll be pleased to answer any questions that the Subcommittee may have. Thank you very much.

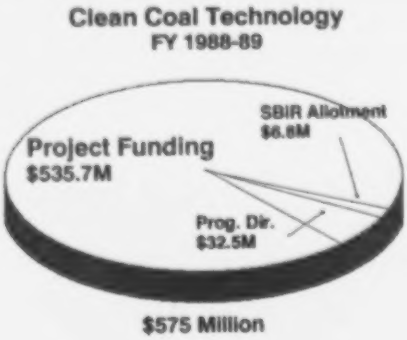
[The prepared statement of Mr. Wampler follows:]

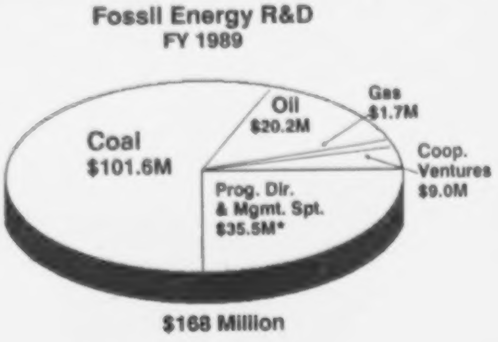
Statement of
J. Allen Wampler
Assistant Secretary for Fossil Energy
U.S. Department of Energy
to the
Subcommittee on Energy Research and Development
Committee on Science, Space and Technology
U.S. House of Representatives
March 2, 1988

Continued implementation of the President's expanded clean coal technology program undergirded by a sound coal research and development (R&D) effort, a new emphasis on the enhanced recovery of oil, and the initiation of a two-phase cooperative R&D venture program highlight the Administration's FY 1989 fossil energy technology budget request. The following testimony describes these key elements of the budget request as well as providing individual fact sheets on each budget item contained in the proposed Fossil Energy program.

Introduction

The two major components of the Department of Energy's fossil energy technology program are (1) the Clean Coal Technology Program, which provides cost-sharing for large-scale, near-commercial demonstrations of emerging coal-based technologies, and (2) a diverse array of more fundamental, smaller-scale research and development efforts in coal, oil and unconventional natural gas. The two programs, depicted below with their major funding components, are complementary efforts – the more fundamental R&D efforts generating the new concepts that are too high-risk or long-term for private sector financing alone, while the Clean Coal Technology Program is providing matching funds to industry to demonstrate the most promising coal concepts emerging from the nation's research and engineering laboratories.





*Includes Capital Equipment

The FY 1988-89 budget for the Clean Coal Technology Program ($50 million in FY 1988 and $525 million in FY 1989) reflects the appropriations approved by Congress in Pub. L. 100-202 for the first two years of the President's proposed five-year program. As will be described in this testimony, the Administration proposes to restore reductions made by Congress in the initial funding level by requesting advanced appropriations of $1.775 billion for FY 1990, 1991 and 1992 to ensure the federal government's full amount of the President's March 1987, $5 billion, five-year clean coal commitment ($2.5 billion of which is the federal share).

The $168 million funding request for the Fossil Energy R&D program ($167 million when a proposed $1 million offset is included) is a 53% reduction from the $354 million appropriated in FY 1988. The funding request is $17 million **higher** than the fiscal year 1988 *request.* As shown by the chart below, six of the nine major categories in the Coal program show proposed FY 1989 increases over their comparable FY 1988 requested levels. The Enhanced Oil Recovery program would increase by more than 75 percent over the department's FY 1988 requested *amount. Given current fiscal constraints, we believe the FY 1989 budget request for Fossil Energy R&D is both technically prudent and fiscally sound.*

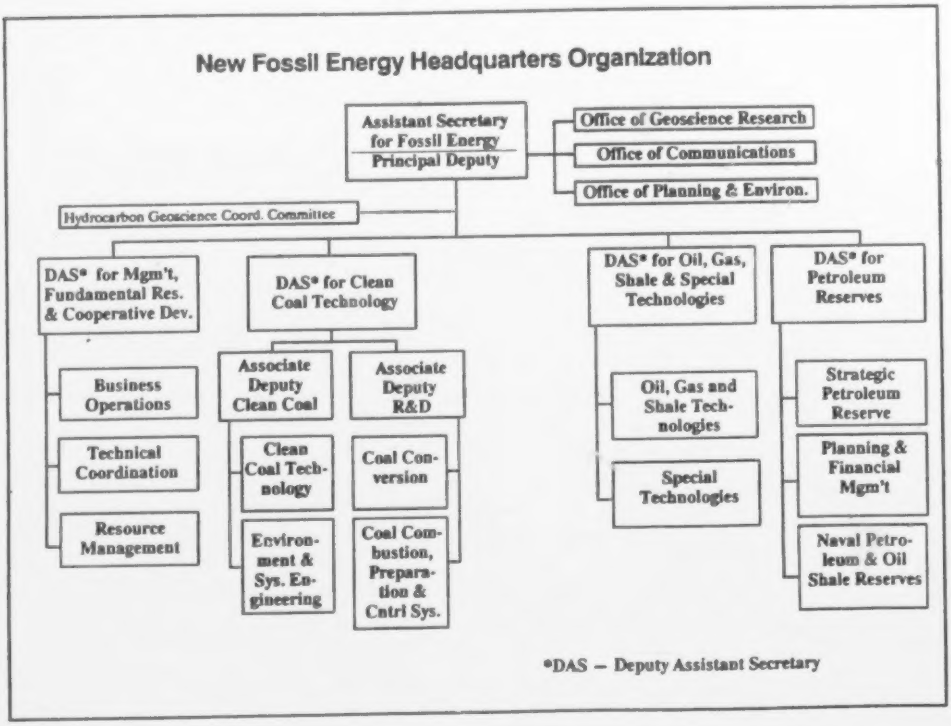
FOSSIL ENERGY RESEARCH AND DEVELOPMENT

	FY 1988		FY 1989
	Request	Approps	Request
COAL			
Control Technology & Coal Preparation	$ 29.69	$ 43.62	$ 31.49
Advanced Research & Technology Development	20.75	24.94	21.41
Coal Liquefaction	9.50	27.13	10.30
Combustion Systems	21.09	25.17	17.42
Fuel Cells	6.58	34.20	6.63
Heat Engines	8.30	17.95	9.00
Underground Coal Gasification	0	2.78	0.27
Magnetohydrodynamics	0	35.00	0
Surface Coal Gasification	5.80	22.99	5.03
Subtotal, Coal	101.70	233.77	101.55
PETROLEUM			
Advanced Process Technology	2.00	3.43	2.17
Enhanced Oil Recovery	9.30	16.54	16.98
Oil Shale	0.96	9.50	1.04
Subtotal, Petroleum	12.26	29.46	20.19
GAS			
Unconventional Gas Recovery	1.60	10.53	1.73
Program Direction & Management Support			
Program Direction	38.44	61.84	34.78
Federal Inspector - Alaskan Gas Pipeline	0.23	0.23	0.25
Subtotal, Prog. Dir. & Mgm't Spt	35.70	62.08	35.03
Plant & Capital Equipment			
Capital Equipment	0.48	0.48	0
Construction	0.0	17.75	0.50
Subtotal, Plant & Capital Equip.	0.48	18.23	0.50
Cooperative Ventures	4.50	0	9.00
Offsets	-6.10	-27.10	-1.00
Total	**$149.65**	**$326.98**	**$167.00**

Fossil Energy Organization

To implement the expanding Clean Coal Technology Program and to ensure that it remains closely aligned to the ongoing related coal R&D programs, significant changes were made in the Office of Fossil Energy's headquarters organization effective on February 29, 1988. The revised organization also realigns several supporting functions within the organization to reflect more accurately the day-to-day operations of the program.

Simultaneously with the organizational restructuring, several senior-level Fossil Energy management officials have been given new assignments within the headquarters organization. These changes will help to ensure that the Office of Fossil Energy benefits from new ideas and management approaches and that expertise gained in one research area can be transferred and applied in other programs. The new Fossil Energy organization is depicted below: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Naval Petroleum & Oil Shale Reserves

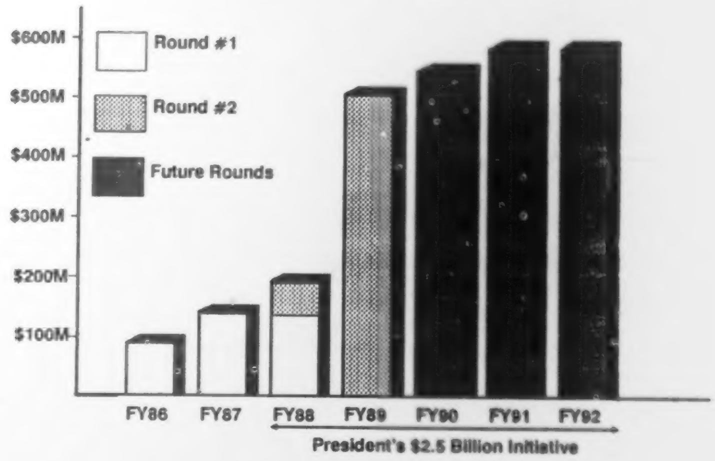
*DAS — Deputy Assistant Secretary

Key Elements of the Budget Proposal

Innovative Clean Coal Technology - The President's commitment on March 18, 1987, to request the full amount of funding recommended by the U.S.-Canadian Special Envoys on Acid Rain placed this nation on an aggressive course toward becoming the world's showcase of new, highly efficient, clean-burning coal technologies. The Innovative Clean Coal Technology Program would feature a sequence of competitive solicitations between fiscal years 1988 and 1992. The staggered timetable of solicitations will encourage new, potentially improved clean coal concepts to continue their development progress and to be considered in future competitions.

The $2.5 billion (federal share), five-year program proposed by the President incorporates a portion of, and builds onto, an ongoing $400 million effort approved by Congress in FY 1986, as shown by the chart below. The initial effort (FY86-88) has, to date, resulted in the successful negotiation of seven clean coal demonstration projects with a total value in excess of $757 million (the federal share projected to be $227 million). Four additional projects are being negotiated to complete the $400 million "first round" competition. (As the chart shows, the President's five-year program includes $150 million in FY 1988 funding applied in Round #1.)

Clean Coal Technology – Funding Profile



The funding level requested by the Administration last year to implement the FY 1988-89 portion of the President's initiative was $850 million. Congress approved $575 million, of which $535.7 million will be made available in matching funds for cooperative agreements (the remainder is required for program direction and statutory requirements). DOE issued a solicitation on February 22, 1988, to begin the initial round of the expanded clean coal competitive program. Proposals are due on May 23, 1988, and candidate projects will be selected on or before the Congressionally directed deadline (in October).

The President remains committed to implementing the full $5.0 billion clean coal program within the five years recommended by the Special Envoys. This was reemphasized in a White House statement issued on January 23, 1988. Accordingly, the department is requesting that the remaining $1.775 billion be made available as an advanced appropriation in FY 1989 to be used for subsequent solicitations in 1990 through 1992 ($575 million to be made available in FY 1990, $600 million in FY 1991 and $600 million in FY 1992).

Continued Coal Research and Development – The FY 1989 budget proposal also maintains a solid core of coal-related research and development. This program, in many respects, provides the "seed money" for advances in knowledge and technical concepts that might ultimately lead to new breakthroughs and innovations in coal technology. While the annual funding level is smaller in comparison to the Clean Coal Technology Demonstration program, the R&D program is of equal importance.

Projects financed under this program are typically smaller in scale, and many are carried out in academic and private sector research laboratories (in contrast to the large demonstration projects that comprise the Clean Coal Technology Program). The value of this more fundamental program, however, is reflected in the significant advances it has fostered in the last decade. For example, since 1980, the coal R&D program has stimulated the development of:

- The **fluidized bed combustion** technique, now commercially deployed in the large industrial sector and gaining a foothold in the utility sector, including commercial-scale projects being financed in the Clean Coal Technology Program;
- **High-temperature gas cleanup** techniques that characterize "2nd-generation" gasification-combined cycle now being demonstrated in the Clean Coal Technology Program;
- The **coal-oil coprocessing** concept, originally studied in the Advanced Research and Technology Development Program, and now being demonstrated in the Clean Coal Technology Program as an economical "bridge" to the future production of synthetic liquids from coal;
- **Coal-slurry mixtures**, also originally studied in the Advanced Research and Technology Development Program, which will likely be a key fuel form for such concepts as the coal-fired diesel and turbine;
- **Underground coal gasification** which has moved from small scale development to the threshold of commercial demonstration during the last decade;
- A new array of **more effective and more economical pollution control devices**, such as electron-beam and copper oxide flue gas scrubbing, and **advanced coal preparation techniques**, many of which rely on such advances as ultrasonic grinding; and
- New insights into potentially revolutionary concepts in **microbial-based coal desulfurization** and conversion.

These advancements will help shape the future of coal technology in the 21st Century. The proposed FY 1989 budget will build on this solid base of technological progress.

In FY 1989 key research efforts will continue in physical and chemical/biochemical coal cleaning, in fine coal cleaning and in advanced flue gas and gas stream cleanup techniques. Work will also continue on novel catalytic, biological and other approaches to coal liquefaction, on benchscale development of coprocessing and/or staged liquefaction, and on the conversion of coal-derived gaseous feedstocks to liquid fuels. Coal gasification research will continue with ongoing efforts in such areas as hot gas desulfurization in entrained flow gasifiers, zirconia oxygen separation, low-energy consumption hydrogen separation and mild gasification.

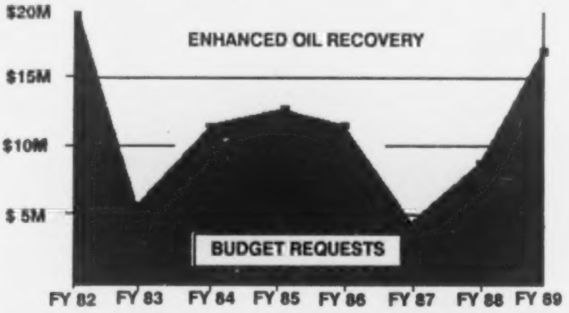
New coal combustion techniques will also continue to be studied with a focus on small scale atmospheric fluidized bed concepts, on key elements of pressurized fluidized bed technology, on advanced, non-fluidizing combustors for industrial, residential and commercial use, and on the transport, handling and combustion of coal-based slurry fuels. The FY 1989 budget also continues development of integrated coal-based gas turbine and diesel engine systems, although the number of private contractors in the program would be reduced. Fuel cell funding would concentrate on resolving remaining technical uncertainties in the molten carbonate technology and continuing the development of the solid oxide technology.

Sufficient funds either exist in the FY 1988 budget or are included in the FY 1989 request to complete several key research efforts, including the Gravimelt coal cleaning process, the fluid bed copper oxide flue gas cleanup technology, the staged coal liquefaction concepts tested at Wilsonville (AL), the liquid phase methanol synthesis technique tested at LaPorte (TX), phosphoric acid fuel cell development, a three-year underground coal gasification field test effort in Wyoming, and the Waltz Mill (PA) integration tests of gasification and hot gas clean-up. As in previous Administration requests, the department is recommending that federal support be withdrawn from the multiyear magnetohydrodynamics (MHD) development effort due to its unaffordable costs, particularly given the diversity of technological options now becoming available to industry.

Enhanced Oil Recovery Initiative – Continued advance of oil production technology is vital to this country. Regulatory reform, tax incentives and other financial measures will not resolve the fact that nearly two-thirds of our oil wealth is inaccessible through conventional recovery. Our target must be the approximately 300 billion barrels of domestic oil that cannot be recovered with today's technology. Much of this oil cannot be moved by conventional means (immobile) or is mobile but has been bypassed by current production methods.

To address this substantial and inviting energy target, the FY 1989 budget proposal contains an initiative to broaden the department's ongoing Enhanced Oil Recovery (EOR) Program. Several EOR research efforts have been reoriented toward shorter-term objectives, reflecting the current inability of the petroleum industry to finance this type of research on its own. New program elements have been added, some of which will be initiated in the remaining months of FY 1988. Included will be an effort to characterize a broad spectrum of the nation's oil reservoirs to gain a better, quantitative understanding of their "anatomy" – their structures, geometries, compositions and how they respond to fluid injection. Also included will be selected field tests, environmental research, and exploratory efforts in oil mining and new concepts such as microbial-based recovery techniques. A strong geoscience component will be included along with other fundamental chemical, physical and thermodynamic studies.

The enhanced oil recovery initiative emerged from months of discussions with oil company officials, academic researchers, trade associations and state agencies. We believe we have crafted a program that represents a consensus approach recommended by these private and public sector experts. The budgetary results of this new emphasis in petroleum recovery is that the department's FY 1989 request for EOR is higher than any comparable request since FY 1982, as shown by the funding chart below:



Unconventional Gas Recovery – The $1.7 million requested for research in the recovery of unconventional natural gas is sufficient to permit the department to assess the results of significant field tests and research efforts that have occurred in this program during the last five to six years, and to continue in-house, geoscience-oriented gas research. The recently completed Multiwell Experiment in the tight gas sand formations of Colorado has provided a wealth of new information which is now being documented. A directionally drilled, horizontal borehole test in an Eastern gas shale deposit in West Virginia has similarly generated substantial information that must be assessed before further research directions are determined. Within the geoscience focus of the proposed FY 1989 unconventional gas program, research will continue in gas hydrates and other long-range gas resources.

Cooperative R&D Ventures – The FY 1989 proposal for a cooperative R&D venture program is an outgrowth of a concerted effort to obtain the private sector's advice and opinion. In contrast to previous proposals in this area, the FY 1989 initiative reflects greater consideration of funding priorities and on program goals and funding requirements in future years.

The FY 1989 proposal envisions the start of a two-phase program. The first phase would build on experiences gained from a pilot cooperative venture activity supported by Congress in FY 1988 ($1 million). It would require $9.0 million in FY 1989 funding and a total of $27 million over an estimated four year period. Highest priority in this initial phase would be given to ventures that would increase the effective domestic resource base for moderately-priced liquid and gaseous fuels. If funds remain available, additional projects would be selected that could increase the contribution of coal by improving its environmental, technical and economic performance in industrial and commercial applications now dominated by oil and gas. A second phase of cooperative R&D ventures would be added beginning in FY 1990 requiring additional funding.

As in previous DOE budget requests for cooperative R&D venture funding, the program would enable the department to join private sector sponsors in the formation of joint ventures that address precompetitive stages of fossil energy technology development. Also consistent with previous proposals, the non-federal venture partners would contribute more than 50 percent of the venture funding. The cooperative ventures would be structured in such a way as to return to the U.S. Treasury the federal contributions if a venture ultimately leads to successful application of the R&D products.

The following pages describe the individual elements of the FY 1989 Fossil Energy budget request.

INNOVATIVE CLEAN COAL TECHNOLOGY PROGRAM

FUNDING ACTIVITIES	FY 1987	FY 1988	FY 1989	% Change from FY 1988
	(Dollars In Millions) (Parenthesis Indicate Round #1)			
Cooperative Agreements (Non-Add)	($145.3)	($145.3)	0.0	(-100.0%)
(New BA)	0.0	$31.1	$504.6	+1,522.2%
Program Direction				
(Non-Add)	($2.0)	($2.0)	0.0	(-100.0%)
(New BA)	0.0	18.5	14.0	-24.3%
Small Business Innovation Research (Non-Add)	(1.8)	(1.8)		
(New BA)		0.4	6.4	
Total (Non-Add)	**($149.1)**	**($149.1)**	**(0.0)**	
Total (New BA)	**0.0**	**50.0***	**$525.0**	**+950.0%**

* Total Appropriation for FY 1988 is $199.1 M.

Background

- The goal of the CCT Program is, as stated in Pub. L. 99-190, "for the purposes of conducting cost-shared clean coal technology projects for the construction and operation of facilities to demonstrate the feasibility of future commercial operation." The Administration proposes to expand the existing program to support the Joint Envoys recommendations on the demonstration of innovative control technologies (i.e., the ICCT Program) over a five year period.

- The FY 1988 budget request included the initial increment of President's March 1987 commitment to requested $2.5 billion in federal funding over a five-year period for innovative control technology demonstration to be matched at least with 50 percent cost sharing by project sponsors.

- Specifically, an additional $50 million was appropriated in FY 1988 and $525 million for FY 1989.

- The remaining $1.775 billion is requested as an advanced appropriation in FY 1989 to be used for subsequent solicitations with $575 million becoming available in FY 1990, $600 million in FY 1991 and $600 million in FY 1992.

- The next solicitations, including the one issued February 22, 1988, will provide financial assistance awards for projects that employ technologies capable of retrofitting or repowering existing facilities.

FY 1989 BUDGET (AS APPROPRIATED IN FY 1988)	Dollars In Millions
• **CCT-1 Cooperative Agreements (Round #1)** - Complete construction on many projects and initiate or continue operational test program for several development efforts utilizing prior year funding. (FY 1988 - $147.1M)	$ 0.0
• **ICCT Cooperative Agreements (Round #2)** - Complete negotiations and initiate projects resulting from the new solicitation for financial assistance that will focus on retrofit or repowering projects. (FY 1988 - $31.5M)	504.6
• **Proposed funding for Small Business Innovation Research** (FY 1988 - $2.2M)	6.4

FY 1989 Budget (con'd)	Dollars in Millions
• **Program Direction**	
- Continue support of operational test program projects in first CCT solicitation using prior year funding. (FY 1988 - $5.8M)	0.0
- Continue efforts to prepare necessary evaluations, status reports, presentations, etc. as may be required to describe the expanded program and its progress to accomplishing the existing as well as added objectives. Continue project technology, market assessments required to evaluate and direct the greater number of projects selected to demonstrate innovative control technologies. Continue analysis of project data and results to ensure consistency with intent of Special Envoy's Report and program objectives. (FY 1988 - $6.0M)	5.9
- Continue environmental assessment studies and operational monitoring programs for projects selected in the initial CCT solicitation using prior year funds. Continue expanded environmental evaluation and data acquisition program required to implement NEPA requirements for each of the increased number of projects as well as the expanded program. (FY 1988 - $4.8M)	3.9
- Provide salaries, benefits, travel expenses, etc. for 58 FTEs (FY 1988 - $4.0M)	4.2
Total FY 1989	**$525.0**

COAL R&D

CONTROL TECHNOLOGY & COAL PREPARATION

(Dollars in Millions)

FUNDING ACTIVITIES	FY 1987	FY 1988	FY 1989	% Change from FY 1988
Advanced Research	$ 1.1	$ 2.0	$ 1.8	-10.0%
Coal Preparation	11.0	15.8	9.9	-37.3%
Flue Gas Cleanup	12.9	14.5	13.0	-10.3%
Gas Stream Cleanup	13.1	9.9	5.4	-45.4%
Waste Management	0.9	1.4	1.4	0.0%
Total	**$39.0**	**$43.6**	**$31.5**	**-27.8%**

Background

- Advanced Research, generic and fundamental in nature, is conducted on processes used to separate constituents such as ash, sulfur and nitrogen oxides in coal fuel streams before, during and after combustion.

- **Coal Preparation** is directed toward the development of advanced coal cleaning technologies that will reduce the ash and sulfur content of U.S. coal so that the product can be formulated into a high quality fuel that could replace oil and/or gas and reduce environmental emissions of suspected acid rain precursors from coal-fired boilers in both new and retrofit applications. Research is conducted in three broad areas: (1) physical treatment and cleaning; (2) chemical/biological pretreatment and cleaning; and (3) engineering support and ancillary operations.

- **Flue Gas Cleanup** addresses the removal of pollution causing contaminants from fossil fuel fired systems to meet current and projected environmental standards that could serve to limit the utilization of fossil fuels. Efforts will be focused on research and development of processes for the removal of NO_x, SO_x, and particulates, both for utility and industrial applications.

- **Gas Stream Cleanup** includes the technology for removal of contaminants from gasifier and combustor process streams prior to utilization in coal conversion systems. Both hardware and environmental protection are key concerns. Applications include PFB combustors, integrated gasifier combined cycle turbines, direct coal-fired turbines, coal-fueled diesels and fuel cells.

- **Waste Management** focuses primarily on waste sampling and characterization from coal preparation and emerging technology wastes.

FY 1989 BUDGET REQUEST	Dollars In Millions
• **Advanced Research**	
· Continue fundamental research on processes used to separate constituents in coal-based fuel streams. Continue program management support. (FY 1988 - $2.0M)	$ 1.8
• **Coal Preparation**	
· Continue research and explore new concepts for physical and chemical/biochemical coal cleaning. Continue research on new technologies for controlling emissions from pre-NSPS utility boilers. (FY 1988 - $6.3M)	4.9

FY 1989 BUDGET (cont'd)	Dollars in Millions
• **Coal Preparation (cont'd)**	
- Continue DOE/EPRI testing of most promising advanced concepts for fine coal cleaning. (FY 1988 - $2.2M)	2.1
- Continue in-house research on advanced physical and chemical coal cleaning concepts. Continue organic sulfur chemistry. Characterize feed coal and coal cleaning products, and study the role of surface functional groups in coal treatment. Continue program management support. (FY 1988 - $2.6M)	2.9
- Completed or discontinued activities: low rank coal beneficiation, Gravimelt project, and coal cleaning research at SIU and Ames Lab (FY 1988 - $4.65M)	0.0
• **Flue Gas Cleanup**	
- Complete research on TUNG scrubbing process. Participate in EPRI high sulfur coal test facility Continue spray dryer and in-duct technology development and systems integration studies for low cost duct injection. (FY 1988 - $3.3M)	2.9
- Continue research on advanced NO_x/SO_2 chemistry and systems modeling. Conduct economic assessments for scaleup. (FY 1988 - $3.2M)	2.9
- Continue advanced NO_x control research. (FY 1988 - $0.3M)	1.2
- Complete fluidized bed copper oxide proof-of-concept evaluation. Continue moving bed process evaluation. (FY 1988 - $1.5M)	2.2
- Continue research on most promising advanced flue gas processes for removal of SO_2 and NO_x at larger scale. (FY 1988 - $1.9M)	2.0
- Continue research on fine particulate control in coal-fired boilers. Initiate larger scale tests of fine particulate control technology. (FY 1988 - $0.8M)	1.0
- Continue research on enhanced mass transfer for duct injection. (FY 1988 - $0.5M)	0.5
- Continue technical and program management support. (FY 1988 - $0.3M)	0.3
- Completed or discontinued projects: research on dry sorbent SOx control, advanced separation technolgy, Glo-Klen boiler tests, and NOx/SOx spray dryer. (FY 1988 - $1.4M)	0.0
• **Gas Stream Cleanup**	
- For Pressurized Fluidized-Bed Combustion, complete long-term test of ceramic cross flow filter. (FY 1988 - $0.2M)	0.3
- For Integrated Gasification Combined Cycle, complete subpilot scale evaluations for cross flow filter and construction of desulfurization tailgas recycle to fixed-bed gasifier test facility; continue testing sulfur control devices at bench scale and development of novel sorbents and novel reactors. (FY 1988 - $4.3M)	3.0
- For Direct Coal-Fired Turbines, continue subpilot scale testing of acoustic agglomeration and development of integrated low emissions concepts. (FY 1988 - $2.3M)	1.8
- Continue systems analysis and program management support (FY 1988 - $2.4M)	0.3
- Completed or discontinued projects: MCFC tolerance assessment (FY 1988 - $0.6M)	0.0

- **Waste Management**

- Continue sampling and characterization of organics and metals in solid wastes, and multi-site field monitoring of disposed wastes. Complete waste management systems analysis. (FY 1988 - $1.0M)	1.2
- Continue characterization of wastes, waste-related data base maintenance, and program management support. (FY 1988 - $0.2M)	0.2
Total FY 1989	**$31.5**

ADVANCED RESEARCH AND TECHNOLOGY DEVELOPMENT

(Dollars in Millions)

FUNDING ACTIVITIES	FY 1987	FY 1988	FY 1989	% Change from FY 1988
Coal Utilization Science	$ 4.9	$ 4.5	$ 3.1	-31.1%
Materials and Components:				
Materials	6.8	6.5	5.1	-21.5%
Components	1.7	2.0	1.5	-25.0%
Subtotal, Materials and Components	$ 8.5	$ 8.5	$ 6.6	-22.3%
Technology Crosscut:				
Environmental Activities	2.2	2.4	2.6	+8.3%
Technical and Economic Analyses	2.0	1.5	2.6	+73.3%
Technology Base Synthesis	1.8	0.0	0.0	
International Program Support	0.0	0.0	0.7	
Instrumentation and Diagnostics	1.7	1.5	1.3	-13.3%
Bioprocessing of Coal	0.0	1.0	0.2	-80.0%
Subtotal, Technology Crosscut	$ 7.7	$ 6.4	$ 7.4	+15.6%
University/National Laboratory Coal Research:				
University Coal Research	5.5	5.5	3.9	-29.0%
University/National Laboratory Cooperative Program	0.0	0.0	0.4	
Subtotal, University/National Cooperative Program	$ 5.5	$ 5.5	$ 4.3	-21.8%
Total, Advanced Research and Technology Development	**$26.6**	**$24.9**	**$21.4**	**-14.1%**

Background

- The Advanced Research and Technology Development (AR&TD) Program is directed toward the scientific and technical areas that underlie the development of all fossil energy technologies.
- The AR&TD coal utilization science program focuses on mission-oriented fundamental research to increase understanding of the mechanisms of direct coal utilization.

Background (con'd)

- The AR&TD Program includes generic studies of materials and components and investigations of instrumentation concepts in environments associated with advanced coal technologies.
- The AR&TD Program undertakes feasibility investigation and exploratory research of novel concepts in coal conversion and utilization.
- The AR&TD Program differs from the Fossil Energy line programs; the latter have an end-item technology development orientation while AR&TD's mission is to pursue generic research in support of all Fossil Energy coal line programs. It addresses fundamental scientific and engineering problems that are barriers to Fossil Energy technological goals. The AR&TD program is unique in that it is directed to specific scientific and technical areas which are closely connected to long-range Fossil Energy objectives.
- Part of Direct Utilization funding was transferred to Advanced Research within Control Technology and Coal Preparation, Combustion Systems and Fuel Cells to comply with FY 1988 Congressional direction.

FY 1989 BUDGET REQUEST	**Dollars In Millions**
• **Coal Utilization Science**	
- Continue, at a reduced level, investigations of the formation, transformation and characterization of fuel and combustion product species; coal devolatilization, pyrolysis and volatile char oxidation; and radiant heat transfer. Continue, at a reduced level, studies specific to low-rank coal. Includes in-house research performed by METC and PETC. Continue to fund technical and program management support. (FY 1988 $4.5M)	$ 3.1
• **Materials**	
- Continue research on advanced steam cycle alloys, mechanisms of erosion and corrosion, ceramics composites, and advanced aluminides. Continue development of superconducting oxides. Continue to fund technical and management support. (FY 1988 - $6.5M)	5.1
• **Components**	
- Continue efforts initiated in FY87 for controllable letdown and alternate flow concepts. Initiate low pressure turbine flow control, nozzle development, and fluidic fuel injection for diesels and unique flow control concepts. (FY 1988 $0.5M)	0.6
- Continue fundamental research on solids transport. Continue to fund technical and program management support. (FY 1988 - $1.5M)	0.9
• **Environmental Activities**	
- Continue analyses of issues associated with air and water quality, solid waste disposal, and toxic substances. Continue support of occupational health, quality assurance, and safety compliances services. (FY 1988 - $1.7M)	1.9

FY 1989 BUDGET (Cont'd)	Dollars in Millions
• **Environmental Activities (cont'd)**	
- Continue research conducted under NAPAP with emphasis on quality assurance of data and analytical tools. (FY 1988 - $0.7M)	0.7
• **Technical & Economic Analyses**	
- Continue generic studies supporting multi-year planning, FE strategy and program formulation; conduct contract studies that crosscut a number of FE programs, fund IEA/Coal Research Service activities. Continue coal technology export and linkage studies, planning, and evaluation. (FY 1988 - $1.5M)	2.6
• **International Program Support**	
- Conduct analyses, studies and technical evaluations of the IEA and bilateral agreement activities in which the FE program is involved. (FY 1988 - $0.0M)	0.3
- Support international collaborative research activities in Fossil Energy. (FY 1988 - $0.0M)	0.4
• **Instrumentation and Diagnostics**	
Continue investigation of fiber optic sensor combustion probes and spectroscopic hot gas stream analysis techniques. Continue to fund technical and program management support. (FY 1988 - $1.5M)	1.3
• **Bioprocessing of Coal**	
- Continue, at a reduced level of effort, fundamental research in the bioprocessing of coal to gain an improved understanding of the reactions occurring when coal is desulfurized or converted to gases or liquids by biological means. Continue program and management support. (FY 1988 - $1.0M)	0.2
• **University Coal Research**	
- Support approximately 22 new grants at universities on the ongoing research topics including coal science, reaction chemistry, surface science, advanced process concepts, thermodynamics, engineering fundamentals, and environmental sciences; continue encouragement of collaboration between university and industrial researchers. (FY 1988 - $5.5M)	3.9
- Initiate one joint project involving collaboration of a national laboratory with universities in an area such as enzyme incorporated membrane processes, superconductivity applications in catalysis and beneficiation, supercomputers for molecule design, and laser-induced chemistry. Continue to fund technical and program management support. (FY 1988 - $0.0M)	0.4
Total FY 1989	**$21.4**

COAL LIQUEFACTION

	(Dollars in Millions)			
FUNDING ACTIVITIES	FY 1987	FY 1988	FY 1989	% Change from FY 1988
Advanced Research	$ 4.5	$ 6.1	$ 3.2	-47.5%
Direct Liquefaction	11.9	13.4	3.2	-76.1%
Indirect Liquefaction	6.2	6.6	2.8	-57.6%
Support Studies/Engineering Evaluation	1.4	1.0	1.1	+10.0%
Total	$24.0	$27.1	$10.3	-62.4%

Background

- This program supports basic and applied research to develop advanced technology for the production of synthetic liquid fuels from coal. The Department focuses upon several approaches to produce liquid fuels from coal: direct liquefaction, indirect liquefaction and novel approaches.

FY 1989 BUDGET REQUEST	Dollars in Millions
• **Advanced Research**	
- Continue research on: novel catalytic, biological and other approaches to coal liquefaction; improving the understanding of liquefaction processes; and, on physical, chemical and thermodynamic properties of fossil fuel liquids. (FY 1988 - $6.1M)	$ 3.2
• **Indirect Liquefaction**	
- Continue laboratory research at PETC investigating catalysts/reactor systems to efficiently convert coal derived gaseous feedstocks to gasoline, diesel, or jet fuels. Maintain limited laboratory research with industry and universities on alcohol and hydrocarbon fuel process concepts. (FY 1988 - $6.6M)	2.8
• **Direct Liquefaction**	
- Continue PETC in-house research. Maintain limited bench scale industrial research in coprocessing and/or staged catalytic liquefaction. (FY 1988 - $5.4M)	3.2
- Completed or discontinued projects: Wilsonville Liquefaction Facility (FY 1988 - $8M)	0.0
• **Support Studies/Engineering Evaluations**	
- Continue to develop solvent quality characterization and process evaluation information on advanced coal liquefaction processes. Continue novel catalystdevelopment and process studies at Sandia National Lab. (FY 1988 - $1.0M)	1.1
Total FY 1989	$10.3

COMBUSTION SYSTEMS

FUNDING ACTIVITIES	(Dollars in Millions) FY 1987	FY 1988	FY 1989	% Change from FY 1988
Advanced Research	$ 3.3	$ 3.4	$ 2.1	-38.2%
Atmospheric Fluidized Bed Combustion	3.3	2.4	1.7	-20.6%
Pressurized Fluidized Bed Combustion	5.8	7.2	7.1	-1.4%
Advanced Combustion Technology	2.8	3.5	2.7	-22.9%
Alternative Fuels Utilization	3.2	3.7	3.8	+2.7%
Limestone Injection Multistage Burners	0.0	5.0	0.0	-100.0%
Total	$18.4	$25.2	$17.4	-31.0%

Background

- The Department of Energy has developed a program to increase the contribution and application of the nation's coal resources through the development of acceptable combustion systems and fossil-derived fuels for the marketplace.
- The programs within the overall Combustion Systems activity are: Advanced Research, Atmospheric Fluidized Bed (AFB), Pressurized Fluidized Bed (PFB), Alternative Fuels and Advanced Combustion Technology. Funding for the Limestone Injection Multistage Burner (LIMB) program, conducted by EPA is also part of this activity.

FY 1989 BUDGET REQUEST	Dollars In Millions
• **Advanced Research**	
- Continue studies to examine the fundamental aspects of combustion mechanisms, corrosive behavior and deposition of combustion products. (FY 1988 - $3.4M)	$ 2.1
• **Atmospheric Fluidized Bed Combustion**	
- Continue to conduct experimental and analytical erosion studies and AFBC development. (FY 1988 - $0.6M)	0.6
- Complete bench scale testing for one advanced concept for AFBC. (FY 1988 - $0.9M)	0.5
- Complete subsystem development testing for one concept within the Special Applications Program. (FY 1988 - $0.9M)	0.6
• **Pressurized Fluidized Bed Combustion**	
- Continue evaluation of PFB components, design alterations and changes in operating parameters to improve systems reliability, reduce costs and enhance environmental performance. (FY 1988 - $0.5M)	0.7

FY 1989 BUDGET (cont'd)	Dollars In Millions
. Continue modeling studies to predict tube erosion/corrosion and linking criteria. Continue to determine mechanisms for tube wastage alloys for long term testing. Provide technical and program management support. (FY 1988 - $0.5M)	0.7
. Continue R&D at Morgantown Energy Technology Center on PFB economics, systems analyses, and combustion characterization. Continue technology and economic analysis assessments. Evaluate the use of "nonconventional" sorbents in advance PFB systems. (FY 1988 - $1.9M)	1.7
. Continue Advanced Concepts Phase II development and maintain project schedule and scope by testing key critical process components such as the circulating bed required to confirm proof-of-concept. (FY 1988 - $3.6M)	4.0
. Completed or discontinued projects: Grimethorpe follow-on efforts (FY 1988 - $0.5M)	0.0
• **Advanced Combustion Technology**	
. Continue the base program for the development of the most promising advanced combustion systems for retrofit, light industrial, commercial and large residential applications. (FY 1988 - $2.7M)	2.0
. Continue in-house activities including combustion and system characterization of coal based fuels. This activity also includes data base development for technology transfer to the private sector. Provide technical and program management support. (FY 1988 - $0.8M)	0.7
• **Alternative Fuels Utilization**	
. Continue identification, formulation and characterization of coal-based fuels in support of the advanced combustion systems program. This activity includes transport, handling and storage studies, and combustion characterization of beneficiated coal based fuels. Continue project management support and international cooperative research. Assess and test deeply beneficiated coals for retrofitting large pre-NSPS coal-fired boilers for acid rain control. Provide technical and program management support. (FY 1988 - $3.7M)	3.8
• **Limestone Injection Multistage Burners**	
. No activity. (FY 1988 - $5.0)	0.0
Total FY 1989	**$17.4**

FUEL CELLS

(Dollars in Millions)

FUNDING ACTIVITIES	FY 1987	FY 1988	FY 1989	% Change from FY 1988
Advanced Research	$ 1.3	$ 1.5	$ 1.0	-33.3%
Phosphoric Acid Systems	15.5	13.2	0.0	-100.0%
Molten Carbonate Systems	7.6	11.1	3.5	-68.5%
Advanced Concepts	5.0	8.4	2.2	-73.8%
Total	$29.4	$34.2	$ 6.7	-80.4%

Background

- The objective of the Fuel Cells program is to support high risk, high payoff technology base development and to assist private industry in developing hydrocarbon fuel conversion technologies to increase the cost effective, efficient and environmentally acceptable use of conventional and alternative hydrocarbon fuels.

- Advanced research, fundamental and generic in nature, is conducted to better understand the basis of the underlying processes involved in fuel cell operation and to explore novel concepts.

- Phosphoric acid systems have reached a near-commercial technical status with large scale testing underway. The Department proposes that any further technology development should be the responsibility of the private sector.

- The technical feasibility of molten carbonate fuel cells operating at approximately 60 percent electrical conversion efficiency (natural gas to busbar) has been forecasted by single cell testing. The complexity and associated capital costs of advanced fuel cell systems are projected to be less than those for first generation phosphoric acid fuel cell systems.

- The solid oxide fuel cell is an advanced, high temperature solid state fuel cell that offers promise in electric utility and in cogeneration applications in industrial and commercial sectors.

FY 1989 BUDGET REQUEST	Dollars In Millions
• Advanced Research	
- Continue generic research in basic electrochemistry science (FY 1988 - $1.5M)	$ 1.0
• Molten Carbonate Systems	
- Continue development of three coal-fueled molten carbonate fuel cell (MCFC) stack technologies and initiate action to select competitively the most promising MCFC technology. (FY 1988 - $10.3M)	3.3
- Continue technology base research, coal gasification/MCFC system study, and program management support. (FY 1988 - $0.8M)	0.2
• Advanced Concepts	
- Continue development of solid oxide fuel cell (SOFC) technology for a multi-kW generator. (FY 1988 - $6.9M)	1.6

FY 1989 BUDGET (con'd)	Dollars In Millions
• **Advanced Concepts (cont'd)**	
- Continue evaluation of advanced concepts. Conduct coal gasification/SOFC system analysis and materials characterization and development. Continue program management support. (FY 1988 - $1.5M)	0.6
Total FY 1989	**$ 6.7**

HEAT ENGINES

FUNDING ACTIVITIES	FY 1987	FY 1988	FY 1989	% Change from FY 1988
	(Dollars in Millions)			
Gas Turbines	$ 9.0	$11.0	$ 6.8	-38.2%
Diesel Engines	3.1	7.0	2.2	-68.6%
Total	**$12.1**	**$18.0**	**$ 9.0**	**-50.0%**

Background

- The principal goal of this program is to establish technical data which will enable the private sector to assess the commercial viability of coal-fueled power conversion systems. The program focuses on key technical problems associated with substituting coal or coal-derived gaseous fuels for distillate fuels or natural gas in gas turbine and diesel power conversion systems.

- Applications for this technology include industrial cogeneration, combined cycle electric power generation, repowering of existing generating capacity, and both rail and marine transportation.

- The FY 1989 budget request for Heat Engines is believed to be appropriate given the need to reduce the Federal budget deficit. Because of fiscal constraints, it is not appropriate or necessary to fund multiple approaches in this program area.

FY 1989 BUDGET REQUEST	Dollars In Millions
• **Gas Turbines**	
- Continue coal-fueled gas turbine integrated systems testing with two contractors. (FY 1988 - $10.2M)	$ 5.8
- Evaluate coal-based liquids in METC pressurized combustor test stand and test gas cleanup device in METC gas turbine combustor. Continue program management support. (FY 1988 - $0.8M)	1.0
• **Diesel Engines**	
- Continue coal-fueled diesel engine integrated system tests with one contractor. Test novel injection combustion and wear from coal-water mixtures and new fuel forms in METC diesel engine test facility and investigate advanced diesel cycles in METC diesel rig. Continue program management support. (FY 1988 - $7.0M)	2.2
Total FY 1989	**$ 9.0**

UNDERGROUND COAL GASIFICATION

(Dollars in Millions)

FUNDING ACTIVITIES	FY 1987	FY 1988	FY 1989	% Change from FY 1988
Gasification Technology Development	$ 1.2	$ 1.7	$ 0.0	-100.0%
Environmental and Advanced Research	1.2	1.1	0.3	-72.7%
Total	$ 2.4	$ 2.8	$ 0.3	-89.3%

Background

- This program represents viable technologies for in situ conversion of coal to a cleaner burning, easily transportable gaseous fuel.
- Program is directed toward the definition of sufficient technical operational, and environmental parameters to allow industry to make decisions concerning the commercial development of the technology.

FY 1989 BUDGET REQUEST	Dollars in Millions
- Continue environmental compliance, restoration, and reclamation activities at historical UCG test sites as required by law. (FY 1988 - $2.8)	$ 0.3

MAGNETOHYDRODYNAMICS (MHD)

(Dollars in Millions)

FUNDING ACTIVITIES	FY 1987	FY 1988	FY 1989	% Change from FY 1988
Proof-of-Concept Topping Cycle	$16.3	$21.4	$ 0.0	-100%
Proof-of-Concept Bottoming Cycle	7.1	8.6	0.0	-100%
Proof-of-Concept Seed Regeneration	0.2	0.9	0.0	-100%
Systems Studies, Supporting Research and Conceptual Design	2.9	4.1	0.0	-100%
Total	$26.5	$35.0	$ 0.0	-100%

Background

- The FY 1988 MHD program began the design, fabrication and testing of "proof of concept" systems in accordance with the June 1984 cost-shared multiyear program. Long duration "proof of concept" testing is needed for the advancement of the MHD technology to the retrofit demonstration stage. A retrofit demonstration stage is needed for the determination of subsequent commercial application.

FY 1989 BUDGET REQUEST	Dollars in Millions
- No funds are requested for FY 1989. Since an estimated $172 million (in constant FY 1988 dollars) will be needed over the next five years to complete the "proof of concept" program, DOE believes the MHD program is not affordable in light of fiscal constraints, particularly considering other emerging options. (FY 1988 - $35.0M)	$ 0.0

SURFACE COAL GASIFICATION

FUNDING ACTIVITIES	FY 1987	FY 1988	FY 1989	% Change from FY 1988
	(Dollars in Millions)			
Advanced Research	$ 2.8	$ 2.7	$ 0.7	-74.1%
Systems for Power Production	14.4	11.2	0.9	-92.0%
Systems for Industrial Fuel Gas Production	1.2	1.4	0.8	-42.9%
Systems for Synthesis Gas Production	1.8	1.9	1.3	-31.6%
Systems for Coproducts Production	4.1	5.3	0.8	-84.9%
Great Plains Coal Gasification Project	0.4	0.5	0.5	0.0%
Total	$24.7	$23.0	$ 5.0	-78.3%

Background

- The coal gasification program is organized to foster the development of advanced gasifier systems for the production of: electric power, synthesis gas (for synthetic natural gas, indirect liquefaction, and chemical feedstocks), industrial fuel gas, and coproducts (simultaneous production of solids, liquids, and gases). This activity also provides for basic and fundamental research related to Surface Coal Gasification processes including studies of reaction mechanisms and chemistry. Finally, this program supports the continued management and monitoring of the Great Plains Project.

FY 1989 BUDGET	Dollars In Millions
• **Advanced Research**	
- Complete work on the biological conversion of coal to methane. Complete work on the mechanisms of ash agglomeration in fluidized bed gasifiers. (FY 1988 - $2.2M)	$ 0.6
- Complete work on separating hydrogen from synthesized gas using ion exchange membranes. Complete work on the factors controlling cleavage and restoration of bonds. Complete work on study of active carbon site distribution. (FY 1988 - $0.5M)	0.1
• **Systems for Power Production**	
- Continue studies on entrained flow reactors to reduce process severity and increase efficiency of gasification. (FY 1988 - $0.5M)	0.4
- Continue environmental sampling and analysis to characterize process and effluent streams. Provide technical and program management support. (FY 1988 - $0.2M)	0.1
- Continue development and testing of hot desulfurization in entrained flow reactor system for power generation. (FY 1988 - $2.8M)	0.4
- Completed or discontinued activities: GE project for application of hot gas desulfurization to integrated gasifier combined cycle systems and Waltz Mill pressurized fluidized bed gasifier with hot gas clean-up (FY 1988 - $6.9M)	0.0

FY 1989 BUDGET (Cont'd)	Dollars in Millions
• **Systems for Industrial Fuel Gas Production**	
- Continue development of economical methods for oxygen production for use in multi-ton/day plants. (FY 1988 - $0.4M)	0.2
- Continue operation of the fluidized bed reactor at METC as well as continuing support for the planning implementation, and application of the gasification data base. Provide technical and program management support. (FY 1988 - $0.6M)	0.6
- Completed or discontinued activities: hydrogen production from low-rank coal and waste water treatment studies (FY88 - $0.8M)	0.0
• **Systems for Synthesis Gas Production**	
- Continue engineering and technical support for the joint DOE/GRI program. (FY 1988 - $0.4M)	0.6
- Continue development of a novel concept for the separation of hydrogen from coal derived gas. (FY 1988 - $0.1M)	0.2
- Continue systems analysis and model development efforts. Provide technical and program management support. (FY 1988 - $0.2M)	0.5
• **Systems for Coproducts Production**	
- Conduct comparative slow and rapid heating rate experiments to establish a matrix of product yields and to investigate product options for coal-based fuels from mild gasification. (FY 1988 - $0.3M)	0.7
- Continue modeling analysis and system analysis. Provide technical and program management support. (FY 1988 - $0.2M)	0.1
- Completed or discontinued activities: research for high Btu defense fuels (FY88 - $0.5M)	0.0
• **Great Plains Coal Gasification Project**	
- Conduct environmental compliance activities. Complete post operations assessments and information archiving. Provide administrative closeout expenses. (FY 1988 - $0.5M)	0.5
Total FY 1989	**$ 5.0**

PETROLEUM

ADVANCED PROCESS TECHNOLOGY

(Dollars in Millions)

FUNDING ACTIVITIES	FY 1987	FY 1988	FY 1989	% Change from FY 1988
Advanced Exploratory Research	$ 3.3	$ 3.0	$ 1.7	-43%
Arctic and Offshore Research	0.5	0.4	0.5	+25%
Total	$ 3.8	$ 3.4	$ 2.2	-35%

Background

- The Advanced Process Technology (APT) Program pursues new concepts to achieve major increases in efficiency and cost reduction of recovery techniques for oil, gas, and oil shale. Research goals are:
  - to conduct fundamental research relevant to recovery of oil, gas and shale oil.
  - to pursue application of new concepts which may achieve major increases in the recovery of oil, gas and shale oil resources.
  - to develop a fossil energy-related knowledge base that will improve the economics of fossil fuel production in the Alaskan Arctic and expand the reserves.

FY 1989 BUDGET REQUEST	Dollars in Millions
• **Advanced Exploratory Research**	
- Continue a program of fundamental studies including cross-cutting research in petroleum chemistry focusing on structural characterization and determination of a structure-property relationship of heavy crudes, intermediate process streams, products, and byproducts. (FY 1988 - $0.8M)	$ 0.6
- Continue, at a reduced level, research on geoscience and extraction technology and development of advanced instrumentation to measure reservoir characteristics and thermal fronts. ($2.0M)	1.0
- Continue, at a reduced level, research on pollutants in aquifers adjacent to oil, gas, and shale in-situ recovery operations. Continue funding for technical and program management support. (FY 1988 - $0.2M)	0.1
• **Arctic and Offshore Research**	
- Continue generation and acquisition of research data on ice island motions and ice flow interactions with structures; continue Arctic/Offshore oil and gas research and information identification. Continue funding for technical and program management support. (FY 1988 - $0.5M)	0.5
Total FY 1989	**$ 2.2**

ENHANCED OIL RECOVERY

FUNDING ACTIVITIES	FY 1987	FY 1988	FY 1989	% Change from FY 1988
	(Dollars in Millions)			
Heavy Oil	$ 2.4	$ 3.7	$ 4.0	+8.1%
Light Oil	7.2	9.9	13.0	+31.3%
Tar Sands	1.6	2.0	0.0	-100.0%
Pilot Venture Program	0.0	1.0	0.0	-100.0%
Total Enhanced Oil Recovery	**$11.2**	**$16.6**	**$17.0**	**+2.4%**

Background

- Enhanced oil recovery represents a technology that can fill the gap between now and the critical time when the nation will likely rely more extensively on synthetic fuels (also being developed by our Oil Shale, Tar Sands, and Liquefaction programs).

- The Department of Energy has developed a program to conduct generic technology base R&D activities; develop fundamental knowledge that can lead to improved and new process concepts; and to assist industry in obtaining a better understanding of the mechanisms and behavior of advanced and novel EOR processes for the recovery of presently unrecoverable light oil, heavy oil and tar sand resources.

- FY 1989 funding will concentrate upon heavy and light oil recovery research. Developing advanced oil recovery techniques is a major initiative of the Fossil Energy R&D program for FY 1989.

FY 1989 BUDGET REQUEST	Dollars In Millions
• Heavy Oil	
- Continue basic research in mobility control mechanisms of steamflood additives. Define the mechanisms by which foam increases oil recovery and develop analytical and numerical models. Develop relative permeability and capillary pressure data. (FY 1988 - $0.4M)	$ 1.5
- Continue cooperative research with Venezuela on petroleum characterization and recovery studies and expand technical and analytical assessments related to geoscience and reservoir characterization. (FY 1988 - $0.2M)	0.5
- Continue a geoscience characterization program, research in novel extraction approaches to presently deemed unrecoverable, heavy oil resources, and fundamental studies of reservoir characteristics and injection fluid interactions. Provide technical and program management support. (FY 1988 - $1.5M)	2.0
• Light Oil	
- Continue a broad based program of research in light oil recovery techniques for reservoir description and conduct related planning, technical and analytical assessments. (FY 1988 - $3.6M)	4.2
- Continue a geoscience effort and reservoir characterization and related fundamental studies addressing definition of reservoir structure and composition. (FY 1988 - $2.5M)	3.7

FY 1989 BUDGET (cont'd)	Dollars in Millions
• **Light Oil (cont'd)**	
- Continue microbiological studies and explore the feasibility of other novel methods of extraction of residual oil resources. (FY 1988 - $1.0)	1.1
- Continue a research program that utilizes CO_2 and other gas recovery methods in a variety of situations to study and identify displacement mechanisms requisite to efficient, effective and predictable application of these techniques. (FY 1988 - $0.6)	1.8
- Continue industry/state cooperative work to rapidly demonstrate lab scale EOR concepts in mature fields. Develop retrofit technology to reduce stripper well costs. Provide technical and program management support. (FY 1988 - $1.9)	2.2
Total FY 1989	$17.0

OIL SHALE

(Dollars in Millions)

FUNDING ACTIVITIES	FY 1987	FY 1988	FY 1989	% Change from FY 1988
Oil Shale Technology Base	$ 7.7	$6.7	$0.7	-89.6%
Environmental Mitigation	3.2	2.8	0.3	-89.3%
Total Oil Shale	**$10.9**	**$9.5**	**$1.0**	**-89.5%**

Background

- Oil shale technology development represents the development of extraction and conversion processes designed to convert oil shale to a state of liquid fuels.
- The Department of Energy has developed a program to provide a sound technological basis for reduction of economic and environmental constraints to industrial development of the U.S. oil shale resources and to increase the amount of resources that may be used economically. The program will focus on basic research using reference shales to systematically study the chemistry, kinetics, and emissions related to eastern and western shale processing.

FY 1989 BUDGET REQUEST	Dollars in Millions
• Oil Shale Technology Base	
- Continue experiments with reference shales in various generic fast heat-up lab-scale retorts, with mechanistic modeling support. Continue developing a systems analysis capability as well as continuing development and maintenance of an oil shale data base. Provide technical and program management support. (FY 1988 - $2.8M)	$ 0.7

FY 1989 BUDGET (cont'd)	Dollars In Millions
• **Environmental Mitigation**	
- Continue analytical methods development, studies of mechanisms of pollutant generation and fate, process stream characterization, and development of an environmental data base. Conduct planning, technical, and analytical assessments. Provide technical and program management support. (FY 1988 - $0.3M)	0.3
Total FY 1989	**$ 1.0**

GAS

UNCONVENTIONAL GAS RECOVERY

(Dollars in Millions)

FUNDING ACTIVITIES	FY 1987	FY 1988	FY 1989	% Change from FY 1988
Eastern Gas Shales	$0.9	$ 2.3	$ 0.3	-87.0%
Western Tight Gas Sands	5.4	3.3	0.3	-90.9%
Environmental and Advanced Research	1.7	4.9	1.1	-77.6%
Total Unconventional Gas Recovery	**$8.0**	**$10.5**	**$ 1.7**	**-83.8%**

Background

- This program fosters the development of advanced technologies for the extraction of natural gas from currently unrecoverable gas resources by reducing the uncertainty surrounding the potential magnitude of reserves of the unconventional gas resources and the conditions under which they will be produced. The program will develop technologies to the point where concepts are proven and economics established.

FY 1989 BUDGET REQUEST	Dollars In Millions
• **Eastern Gas Shales**	
- Continue in-house support to maintain and update the technical data base and research with associated reservoir and stimulation models; continue systems analysis in support of production strategy development. (FY 1988 - $2.3M)	$ 0.3
• **Western Tight Gas Sands**	
- Continue in-house support to update predictive reservoir and stimulation models; expand technical data base. Continue systems analysis in support of production strategies and also forecasts of regional production patterns in light of multi-well results and reservoir heterogeneity. (FY 1988 - $3.3M)	0.3

FY 1989 BUDGET (cont'd)	Dollars in Millions
• **Environmental and Advanced Research**	
. Continue in-house geologic, geophysical and geochemical studies in support of a program to explore deep source gas generation potential of organics subducted due to plate tectonic convergence. (FY 1988 - $0.2)	0.3
. Continue research to explore, on a fundamental basis, geophysical and geochemical properties of gas hydrates and to examine gas hydrate recovery strategies based on an understanding of the gas release mechanisms. Conduct in-house technology assessment of processes to convert natural gas to liquids. Provide technical and program management support. (FY 1988 - $4.6)	0.8
Total FY 1989	**$ 1.7**

COOPERATIVE R&D VENTURES

	(Dollars in Millions)			
FUNDING ACTIVITIES	FY 1987	FY 1988	FY 1989	% Change from FY 1988
Cooperative R&D Ventures	$0.0	$0.0	$9.0	n/a

Background

- The Administration proposes to initiate a multiyear two-phase program for cooperative research and development ventures in fossil energy technologies.
- The first phase would provide immediate support to those ventures which are currently ready to proceed, and would require approximately $27 million over an estimated four-year period.
- The design of the first phase could be based, in part, on experiences obtained from the pilot cooperative R&D venture activity considered under the Enhanced Oil Recovery program.
- The second phase, in which awards would be made in FY 1990, would support a subsequent set of ventures which will be defined and organized by potential participants in the intervening period. Additional funds beginning in FY 1990 would be required for this second phase.
- The FY 1989 budget request proposes $9,000,000 to enable the Department to join with private sector participants in the formation of cooperative research and development ventures which address precompetitive stages of fossil energy technology development, and in which the non-federal venture partners contribute over 50 percent of the venture funding.

FY 1989 BUDGET REQUEST	Dollars in Millions
• Cooperative R&D Ventures	
- Provide financial assistance awards for cost-shared cooperative R&D ventures that can ease the level of future oil imports by focusing on the development of technologies that satisfy mission objectives to increase the effective domestic resource base for moderately-priced liquid and gaseous fuels; and to increase the contribution of coal by improvements in environmental, technical and economic performance in industrial and large commercial applications currently dominated by oil and gas. Under the Phase I program, higher priority would be given to the first of the above two areas. (FY 1988 - $0)	$8.9
- Provide support for preparing and issuing Phase I solicitation and Phase II Statements of Interest. Monitor activities, and assist parties interested in establishing potential ventures. (FY 1988 - $0)	0.1
Total FY 1989	$9.0

PROGRAM MANAGEMENT & CAPITAL EQUIPMENT

PROGRAM DIRECTION & MANAGEMENT SUPPORT

(Dollars in Millions)

FUNDING ACTIVITIES	FY 1987	FY 1988	FY 1989	% Change from FY 1988
Headquarters Program Direction				
Salaries and Benefits	$ 8.0	$ 9.1	$ 8.4	-7.6%
Travel	0.6	0.5	0.3	-40.0%
Contract Services	3.0	4.4	1.0	-77.2%
Subtotal, Headquarters Program Direction	$11.6	$14.0	$ 9.7	-30.7%
ETC Program Direction				
Salaries and Benefits	$17.5	$19.0	$13.5	-28.9%
Travel	1.0	1.0	0.6	-40.0%
Contract Services	28.5	27.8	11.0	-60.4%
Subtotal, ETC Program Direction	$47.0	$47.8	$25.1	-47.4%
Federal Inspector for the Alaskan Natural Gas Transportation System	$ 0.2	$ 0.2	$ 0.2	0.0%
Total Program Direction	**$58.8**	**$62.1**	**$35.0**	**-43.6%**

Background

- This activity provides funding for salaries, benefits and overhead expenses for the management of FE programs at Headquarters and the Energy Technology Centers:

Background (cont'd)

- The Headquarters staff is responsible for overall program direction which implements DOE policy and communicates that policy to the Energy Technology Centers, sets program objectives, develops program plans and evaluates alternative program strategies, develops and defends budget requests to the Office of Management and Budget and to the Congress, approves procurement plans, monitors work progress, evaluates projects, approves revisions in work plans as required to attain program goals, and supports the new Office of Geoscience Research.

- The Energy Technology Centers support day-to-day project management functions for assigned programmatic areas including contract and National Laboratory monitoring, development and maintenance of project budget, procurement plans, and other activities related to program and site support.

- The Office of the Federal Inspector for the Alaska Natural Gas Transportation System is responsible for coordinating all Federal activities pertaining to the pipeline in order to assure timely, efficient, safe, and environmentally sound construction, including the assessment of developments in the world energy market, specifically the U.S. and Canadian oil and gas situation as they affect the Alaska Natural Gas Transportation System.

FY 1989 BUDGET REQUEST	Dollars in Millions
• **Headquarters Program Direction**	
- Provide funds for salaries and benefits of 125 full time-equivalent (FTE) personnel at Headquarters. This staff implements and communicates policy to the ETC's, sets program objectives, develops program plans and evaluates alternative strategies; develops and defends budget requests; approves procurement plans, monitors work programs. (FY 1988 - $9.1M)	$ 8.4
- Provide funds for travel of 125 FTEs in support of the activities stated above. Both domestic and international travel is conducted. (FY 1988 - $0.5M)	0.3
- Provide for contractual services that are generic to the entire FE program. Included are items such as printing, computer services, technical support services, conferences, etc. (FY 1988 - $4.4M)	1.0
• **ETC Program Direction**	
- Provide funds for salaries and benefits of the ETC staff of 243 FTEs. Activities of the staff include contract and lab monitoring; development and maintenance of project, budget and procurement plans, and other activities related to program and site support. (FY 1988 - $19.0M)	13.5
- Provide funds for travel of 243 FTEs in support of the coordination of the above activities in the attainment of program goals, both on the domestic front and abroad. (FY 1988 - $1.0M)	0.6

FY 1989 BUDGET (cont'd)	Dollars In Millions
- Provide funds for facility operations, maintenance, finance and administrative support and other costs not appropriately chargeable to R&D projects, in support of this level of FTE's. (FY 1988 - $27.8M)	11.0
• **Federal Inspector for the Alaskan Natural Gas Transportation System**	
- Provide funds for administrative and support functions; continue to assess developments in U.S. and Canadian energy markets and maintain liaison with project sponsors, producers, other government agencies, State of Alaska and Canadian government. (FY 1988 - $0.2M)	0.2
Total FY 1989	**$35.0**

PLANT AND CAPITAL EQUIPMENT

(Dollars in Millions)

FUNDING ACTIVITIES	FY 1987	FY 1988	FY 1989	% Change from FY 1988
Capital Equipment	$ 1.6	$ 0.5	$ 0.0	-100.0%
Construction	1.8	17.7	0.5	-97.1%
Total Plant and Capital Equipment	**$ 3.4**	**$18.2**	**$ 0.5**	**-97.3%**

Background

- Capital equipment is purchased annually to replace obsolete equipment so that the Energy Technology Centers (ETCs) and the National Laboratories analytical capabilities are constantly being upgraded.

- General plant projects are essential to the safe, efficient operation of the ETCs and construction is dedicated to a number of improvements, alterations and additions at each of the ETCs.

FY 1989 BUDGET	Dollars In Millions
• **Capital Equipment**	
- No Activity. (FY 1988 - $0.5M)	$ 0.0
• **Construction**	
- Continue design of chemical engineering laboratories project at PETC. (FY 1988 - $0)	0.5
Total FY 1989	**$ 0.5**

DISCUSSION

Mrs. **Lloyd**. Thank you very much, Allen.

I was looking at the chart of the demonstration programs. What is the status of the four new projects selected under CCT–1?

Mr. **Wampler**. Four new projects are currently under negotiation, and I might add that we, in these projects, have mutually negotiated with the private sector partners milestones in which all have to meet as far as negotiation of time lines.

Mrs. **Lloyd**. Is there a deadline for the negotiation?

Mr. **Wampler**. Well, there is a deadline that is mutually agreed on, the last project, as I recall, being in August of this year. However, at that point in time when the project gets to its final deadline, I would have the option to make a decision to look at a possible extension if the project is far enough along that I could reasonably believe that it is going to be negotiated.

Mrs. **Lloyd**. What happens if all four of them don't make it?

Mr. **Wampler**. We still have projects that were on the B list, and those projects would be eligible for reselection.

Mrs. **Lloyd**. Are the ones on the B list still interested in continuing to participate?

Mr. **Wampler**. We have, as I recall, six projects that are still active on the B list, and they are still interested.

Mrs. **Lloyd**. Have any of them dropped out?

Mr. **Wampler**. We have had four projects drop out of the B list. They have withdrawn their statements of interest.

Mrs. **Lloyd**. I understand that some of the utilities are rather hesitant to participate in the Innovative Technology Development using their own money. Is this the case?

Mr. **Wampler**. Well, I think it's important to look at the current projects that we have ongoing and the statements of interest. There are many of those that utilities are participating in one way or the other. If you look at the four projects that we're currently negotiating, three of those have utilities that are participating in funding and sites. They will participate certainly in terms of the host site.

Of the seven that we signed, contracts that are already underway, three of those have utility participation. So we are encouraged that utilities will participate. We think that some of the new deployment features that the Administration is going to be proposing will increase utility participation.

Mrs. **Lloyd**. After all, they will be the ultimate customer.

Is there any sort of relief or incentives that we might provide to encourage more utility participation?

Mr. **Wampler**. I think they certainly are important, and I think there are certainly incentives that we can provide. The President's Task Force——

Mrs. **Lloyd**. Do you have any specifics?

Mr. **Wampler**. Yes—on Regulatory Relief has just announced their encouragement of three specific kinds of incentives that we could provide utilities or Clean Coal demonstration projects to encourage this type of participation. The first is preferential treatment for projects that are located in States that treat innovative technologies the same as pollution control.

Also, there are three FERC incentives that they are encouraging to be adopted that provide for CWIP incentive rates of return, and these are the financial-type incentives that FERC can provide to get these utilities deployed. They have also instructed the Environmental Protection Agency to provide some administrative measures that would encourage the demonstration and deployment of these technologies. I might say that we think this is a good start.

Mrs. LLOYD. I think it is too, since the utilities should be the ultimate beneficiaries of this advanced R&D. To me, it is a wise decision.

Mr. WAMPLER. We think so. We think, also, it is important that, however, as we implement these deployment features, that we constantly evaluate whether or not they are enough to get these technologies deployed, and we intend to do that. The President's Task Force will constantly monitor these incentives to see if they are, indeed, enough for deployment.

Mrs. LLOYD. Very good. I was wondering if you were at liberty to discuss this morning why DOE couldn't reach an agreement with Wierton Steel and General Electric. They were the two projects from the first solicitation who didn't sign an agreement. Were these common problems, or were they unrelated?

Mr. WAMPLER. Madam Chairman, I can discuss it in general terms. The negotiations with both of these organizations were essentially completed at the time that both companies decided to withdraw their proposal from further consideration.

Apparently, both companies had major problems in resolving some internal management and organizational issues that they needed for corporate commitment to this program as well as they had some difficulties acquiring the financial equity that was necessary to finance the project.

Mrs. LLOYD. Very good. In reference to CCT-1, when do you expect these technologies to be ready for the marketplace, or when can commercial plants be built?

Mr. WAMPLER. We are looking at the 1990 to 1995 time frame that these technologies will be ready in all cases. Some of these technologies would, in fact—it would be possible to deploy in the early part of that time frame because perhaps they do not have to be fully demonstrated before deployment in the case of PFB, AFB, and some of the technologies have been sufficiently proven in their basic form to be deployed.

Mrs. LLOYD. One final point. I'd like for you to describe for us some of the lessons learned by the Department from CCTI and to ICCTII, as reflected in their recently issued Program Opportunity Notice.

Mr. WAMPLER. Well, we learned a lot. In fact, we have a very large document that talks about lessons learned in the first project, and I think, if I would have to summarize, we recognize several basic key things. We didn't incorporate all these in our second PON, by the way.

The first lesson we learned, that many projects need to be selected by the Department before financial lenders are willing to make a commitment or give the project serious consideration. So in our second PON, we request a detailed financial plan of the award plus financing through the first decision point only, and that's the end of preliminary design, and this would be followed by financing for the entire project by the first decision point.

A great deal of time and a great deal of difficulty was incurred in Clean Coal 1 with the private sector having to develop the information needed to proceed from selection to award. More information is required in areas such as management planning, commercialization, and financing plans and commitments for site access, and this was very costly for the participants with no guarantee that they'd be able to reclaim any of these expenditures. So the Clean Coal Technology Program Number 2 provides that we can cost share the pre-award costs that are approved by our contracting officers, only though, however, at the time of the signing of the cooperative agreement with the successful bidders.

The last major lesson that we learned was, the recoupment plan was an extremely difficult portion of the cooperative agreement to negotiate, and that's been reduced by the Department to a very simple formula that will apply to all projects, and it will eliminate complicated negotiations on a case-by-case basis. It is patterned after the private sector's licensing agreements, and we think it should be not nearly as unwieldy as the former recoupment plan.

Mrs. LLOYD. Turning to the second PON, how soon do you expect to make project selections after the May 23 deadline?

Mr. WAMPLER. We have a deadline of the latter part of October. We expect to make selections earlier than that, perhaps as early as the latter part of September. We're moving aggressively with this project selection bit, and we think we'll have no problem at all certainly meeting the deadline date and perhaps expediting as much as a month.

Mrs. LLOYD. Thank you very much.

Mr. Morrison.

Mr. MORRISON. Thank you.

I'd like to spend just a minute back when the relationship between the Fossil Energy R&D Program and Clean Coal Technology—obviously, your decision is to move ahead dramatically with one and, to a certain extent, at the expense of the other. How are you planning to coordinate so that the objectives of both of these programs can be efficiently reached?

Mr. WAMPLER. Well, first, decisions on the programs are arrived at independently, but they are complementary, and they should be complementary. The research program provides very specifically the basis for some of the design and testing that support the demonstration project.

Secondly, the research program is gathering information on the technical problems that we know exist in some of the technologies that we're currently demonstrating, like fluidized beds and tube erosion being one.

Third, if you look at the normal research and development program that we have, you are dealing with constant policy and economic changes in the energy market, and we feel that we need research on advanced coal systems, for example, that more meet the marketplace.

So, our long-term research in some cases is geared to, if you take the case of coal, new market applications for coal, such as the light industrial, residential, and commercial markets.

So while the programs are very complementary, very cross-cutting, the decision on where to spend the money is arrived at with somewhat independent judgment.

I might say that organizationally, in order to facilitate the communication between the two branches, if you will, of coal research, we have Mr. Siegel, who is at the end of the table, is the Deputy Assistant Secretary of Coal Technology, and under him and his organization he has both the Clean Coal Technology and the R&D. We feel that this was a very necessary thing to do, even though it makes his work load tremendous, to make sure that we had an exchange of information, and to make sure that the R&D ideas could flow into the demonstration pipeline when it was required that they do that.

Mr. MORRISON. I know when we went through this drill last year that Congress ended up changing some of your priorities at that time. How much has that shift in funding frustrated what you sense are the proper goals for this country through energy policy?

Mr. WAMPLER. Well, I think the proper goal—and this is a bit of a philosophical point, I suppose, but the proper goal for R&D in this country has to be aimed at the mix of energy supply. It's important that we also keep in mind our indigenous resources, when we design a research and development program, and if you look at indigenous resource two things become immediately apparent. One is that you have a large amount of coal in this country and a parallel resource in coal. The second thing is that you have a lot of oil and gas that can be produced by unconventional methods, by enhanced oil recovery methods. I think any research program that you have in fossil energy has to concentrate on those two areas.

The third area, and the one that we certainly have concentrated on tremendously, is really a part of the first area I was referring to, and that is ways to burn coal in an environmentally-acceptable manner, and that is the reason for the Clean Coal Technology Program. So I think we have to focus on ways to impact the amount of increase in imported oil, ways to back out imported oil, as a general goal.

Mr. MORRISON. Okay. I certainly agree with the goals. I guess I also look at the tendency around this place, and that's sometimes to stick with programs that, you know, we know in some cases that are located properly for ongoing funding, and I guess now that we're in the last year of the Reagan Administration, I maybe sense a little bit of frustration in what you're saying, the lack of support in achieving a couple of your goals.

Just one last question that interests me very much. Your Clean Coal Technology concept is not new in the interface with industry, but I'm wondering, have you worked out in advance how you would share the fruits of your labor? For instance, you're going to have some technology spin-off, you're going to have some patent opportunities from these investments. Has that all been worked out in advance in your interface with private enterprise?

Mr. WAMPLER. If you're referring to technology transfer, an area that's very important to us, we've launched a major effort within the Department in the past year to address the whole area of tech transfer, and I think we have a very good, sound plan in place.

In the area of patents, I think we're well on our way generally in cooperative agreements, which these all are. If the private sector is putting up as much as 30 percent of the funding for the projects, the general rule of thumb is that we let them have the patents and the proprietary rights, and I think that's very proper that we do that because it certainly maximizes deployment if they have it. The Federal Government is ill equipped to sell anything, I've found.

So we've tried, and I think we're well on our way, to taking care of some of those problems. We do currently, however, have committees that work very aggressively within the Department looking at the whole patent issue with the idea of making some major improvements in that issue, and, as I recall, the group will be finished at the end of April with its recommendations. So we're looking forward to that.

Mr. **Morrison**. Okay. We'll look forward to those too, because, to a certain extent, you're doing some pioneering in this area.

Thank you very much, Madam Chairman.

Mrs. **Lloyd**. Thank you, Mr. Morrison.

Mr. Fawell.

Mr. **Fawell**. Thank you, Madam Chairman.

Mr. Wampler, I understand that Argonne, and your office, and the Energy Technology Centers have been working together to develop a core fossil energy research program and other programs in technology analysis and assessment at Argonne National Lab.

I wonder if you could tell us something about the present status of funding for both the research and assessment programs at Argonne, and, further, could you tell us what actions, if any, might be required to implement appropriate funding levels for both the research and the assessment activities?

Mr. **Wampler**. The issue of core R&D versus the other chores we have done at Argonne is probably always an issue. This year, however, as we are projecting—and we did some projection on this as late as yesterday—the one thing I can say is that the funding level for Argonne will be up this year from last year, perhaps by as much as 10 percent.

What we are looking at is a current effort of about $6.5 million for the core R&D program, and the assessment kinds of things that they're doing is about $700,000. So it's a reasonably small portion of that.

So we are aware of the concern to make sure that the core R&D program is strengthened and remains stable, and we'll work to do that, but we also are taken with their ability to do assessment, and that's why we're doing so much of it with Argonne, that they do an excellent job for us, and so I'm sure that area's going to be strengthened also next year, and we'll work very hard not to let that get out of balance. I know they are concerned about it, but I think they're a bit unduly concerned.

Mr. **Fawell**. This is perhaps just a layman's question and shows my ignorance, but at several what we call campaign coffees you have people propound questions, and one person put the question as to—referring to the Clean Coal Technology, and there is a fairly large amount of money being spent there, and he referred to the fact that acid rain is something that, obviously, is an end product that we're all concerned about, and he brought out the fact that, "Well, why isn't there more money put toward new energy sciences other than trying to continue the idea of burning fossil fuels?" Even if we clean them up, I don't know if we're going to be able to do it to the point that there isn't a lot of detrimental end result. But he made the point that, you know, we have to break away from the caveman philosophy of burning fossil fuels basically to get our energy and heat source, and I think it was a fairly decent question and that perhaps we're not emphasizing new energy sources, whatever it may be, fission, or fusion, or hydrogen, or whatever. I wasn't quite sure how I would respond to that. How would you respond to it?

Mr. WAMPLER. Well, I think I would respond by somewhat agreeing with it. I think all these energy sources and potential energy sources are very, very important. I think that the nuclear option has to be pursued; I think it's unfortunate in that particular one—I might make a side comment—that we're dealing with a severe public perception problem, because I think at some point in time we're going to have to have it in this country.

Mr. FAWELL. I would agree with that point.

Mr. WAMPLER. I think that all these sources should be vigorously pursued.

I did hear one of my colleagues make a statement the other day that, no matter how much conservation we exercise and no matter how many of these new energy sources that we pursue, at least in the short term, the short term meaning 20–25 years, we still need supplies of fossil fuels, and I think in the short- to mid-term those are so important to us that we have to spend this kind of money on developing more efficiency from the fossil fuels that we have and cleaner operation and those kinds of things.

Mr. FAWELL. Please understand, I come from Illinois where there's an awful lot of coal, so, politically speaking or practically speaking, I guess I would have to lend a very open ear and willing ear to that philosophy. But I thank you for your response.

That's all the questions I have, Madam Chairman.

Mrs. LLOYD. Thank you, Mr. Fawell.

Mr. Walgren.

Mr. WALGREN. Thank you, Madam Chairman, and I think in any hearing that we have that Assistant Secretary Wampler comes to, I'd like to salute you in terms of the personal approach that you have given to relating to the Congress, both to the Committee as a whole, as the Chairman has said, and to the individual Members. I think you're in certainly a difficult position in an area where budgets have been forcibly declining, and that's a very difficult position for anybody to be in, and I want to say that I personally appreciate the way that you've been open to the Congress.

I wanted to ask about the Coal Preparation and the Flue Gas Cleanup programs where, as I understand it, we are declining in our requests, not a lot of money involved here—$15—almost $16 million last year spent in Coal Preparation, but taking a substantial cut down to $10 million, which would be about a one-third cut, and in Flue Gas Cleanup almost $15 million spent, taking a $2 million reduction down to $13 million or thereabouts.

In Pittsburgh, the Energy Laboratory has emphasized in many ways Coal Preparation, and I've been struck by the potential that has to contribute to the situation.

How does it come about that Coal Preparation would be reduced by a third and Flue Gas Cleanup takes a smaller reduction? Can you give us a background on that?

Mr. **Wampler**. Well, some of the—we're completing some projects. The completion of current efforts probably takes the largest whack out of that, and we completed Gravimelt, the research at SIU and Ames Lab. UNDERC has been taken out of that and is included in that change.

But with your permission, let me say something basically about coal preparation. We're very supportive of coal preparation, and we think that it shows a great deal of promise. I think that, in combination with flue gas cleanup, is also very important.

We are expecting that in Round Two of the Clean Coal Program, we are hoping that we have many good preparation projects suggested for that. We had difficulty with that in Round One, but we're encouraged that people will come forward with those projects in Round Two, and, you know—again, to answer your question, it's simply a matter of balance; it's simply a matter of the thousand projects that we have in coal R&D, and some days I think that the Congress has interests in 999 of those, but it's a matter of balance. But we are supportive of coal preparation and flue gas cleanup in combination. I think it does show a great deal of promise.

Mr. **Walgren**. We have had sharp reductions in this budget, and we are at now $300 million-$326 million; we used to be at $800 million or so.

Am I out of time, Madam Chairman? No.

Were you looking for me?

Mrs. **Lloyd**. No.

Mr. **Walgren**. No, I'm sorry. I thought I might have exhausted the time.

And now we're down another 48 percent. How do you deal with projects that need to be funded and yet you're forced to take reductions on the level of 48 percent? Can you say objectively that we are vigorously pursuing this area from your point of view, or are we essentially sharply bound by budget limits? Which is the right description of our budget effort this year?

Mr. **Wampler**. Well, I think the budget effort this year, with its projected cuts, is a little bit different. It's a little bit different from the standpoint of the close-out of programs. So I think you have to factor about half of that into close-out of programs.

I think that you always look at R&D from the standpoint of some R&D as a function of time and dollars; some is not, and that's always a hard judgment to make because of the very nature of R&D.

I think with the budget that we have proposed, however, we can go forward with a balanced program. In some cases—I'm not naive enough to think that it's not going to slow progress down, but I think that's a natural function of tight money.

So I think what we try to do at the Department is to constantly look at our priorities, and I think we're going through a fresh step of that in the next 90 days for the 1990 budget process has already started within the Department, so we're going to be taking a fresh assessment of that, and I think that perhaps we have to be a little bit more realistic sometimes about R&D that could be closed out a little bit earlier because of lack of results than we are. I think that we have some shortcomings in that area.

But I do think that what we have proffered is balanced. I have always said that there are simply more good projects and more technically sound projects out there than we'll be able to fund in times of tight budget.

Mr. WALGREN. Is that the explanation for the reduction in the Heat Engine activities where we're cutting by 50 percent from a very small amount?

Mr. WAMPLER. No. The Heat Engines activity is a function more of the risk involved. We selected, I guess, four turbines, four contractors, and we built into this program some decision points on purpose because of the risk involved with it, that we could decide at logical points that coincided somewhat or with the budget process, that we could lower those to two contractors, and we did it thinking that it would not affect the success of the science significantly if we did that.

Mr. WALGREN. Maybe we can pursue that separately.

What's been your experience with the SBIR Program? Has that been difficult to integrate into the system? Has it delivered you potential? Is it a good thing?

Mr. WAMPLER. Let me let Jerry Walsh, who is my Deputy Assistant Secretary for Management, answer that, with your permission.

Mr. WALSH. Yes. We have—because of the growth in the Fossil Energy budget over the last few years, especially with respect to Clean Coal, Fossil Energy has been more aggressively pursuing a greater role in the SBIR Program within the Department. This year, as a matter of fact, we've increased the number of topics from three to five in the Fossil Energy area, and we intend to play a very active and vigorous role in reviewing these topics and recommending them for selection.

Mr. WALGREN. Maybe we can follow you up in writing on that, because I'd be interested in your experience specifically with it.

If I could ask one other question, Madam Chairman, how do we fit internationally? We're not the only ones that are doing clean coal research and efforts. How do you compare our program with what's going on overseas? Is it going to result in technologies that you feel will have export potential? Are other nations farther down the road in solving this problem than we are?

Mr. WAMPLER. We generally, Congressman, have a slight technical edge right now, as we sit here today, and we did an assessment of this last year to make sure we were right on that.

There is no doubt, with the $5 billion program—and I'm including the private sector's cost share—that the U.S. will have a suite of technologies that will be far advanced of any other country, and it has tremendous export potential. We're currently doing several studies to identify exactly what that potential is, but we see the potential already existing because many countries have been faced with the same environmental situation that we've been faced with, and we currently have 23 international agreements in place in the fossil energy area, and we're aggressively pursuing all of those to look at export potential for these technologies.

Mr. WALGREN. If I could just ask maybe if you could give us some elaboration on those several studies that you're looking at the export potential for the record, it would be an interesting area for us to consider.

Mr. WAMPLER. Certainly.

[This material is included in the questions and answers for the record below.]

Mr. WALGREN. Thank you very much, Madam Chairman.

Mrs. LLOYD. Without objection, and I have some questions that I would like to submit for the record for you to answer as well, Mr. Secretary.

Mrs. LLOYD. Mr. Boucher, our colleague from Virginia, has agreed to chair the remaining part of the hearings. It is necessary for me to go to Armed Services' hearing at this time. But I would like at this time to welcome a new Member of our committee, Congressman Shays of Connecticut.

We're happy to have you with us today, and we look forward to your participation in the Committee as well.

Mr. Boucher.

Mr. Secretary, I want to thank you for being here. We appreciate your testimony, your interest, and your conscientious efforts on behalf of coal technology.

Mr. WAMPLER. Thank you, Madam Chairman.

Mr. BOUCHER [presiding]. Mr. Secretary, I would join the chair in welcoming you here today.

Mr. WAMPLER. Thank you.

Mr. BOUCHER. I have just a couple of questions of my own. I notice that there's a rather significant decrease in your recommended level of funding for the Heat Engine research category and particularly with respect to research on the use of diesel fuels and locomotives as derived from coal. For the current fiscal year, you have $6.9 million for that purpose, and, as I read your figures, you are recommending a decrease for the next fiscal year to $2.2 million.

I suppose my question is, what are your plans for research in this field? What have you done so far? How are you planning to commit the $6.9 million that you have for the current fiscal year? And why do you think it is appropriate to reduce the funding, in what I think is a very promising area, to a mere $2.2 million for next year?

Mr. WAMPLER. I, too, think it's a very promising area. The program in Heat Engines was initially begun with four contractors. We would plan to cut that number to two contractors at the end of a milestone that we have built into the program, and the reduction in funding simply represents that.

I'd be glad to let—if you would like a status on the activities in fiscal year 1988, I'd be glad to let Jack Siegel give you a brief description of what the research program has——

Mr. BOUCHER. Mr. Siegel, I'd be happy to hear that.

Mr. SIEGEL. Thank you. Can you hear me?

Mr. BOUCHER. I can hear you; I'm not sure others can.

Mr. SIEGEL. Mr. Chairman, in fiscal year 1988 the Department of Energy, through our Morgantown Energy Technology Center, did enter into an agreement with two companies for coal-fired diesel applications. Those were with General Electric, who was going to be doing research on coal-fired diesels for cogeneration and locomotive applications, and Arthur D. Little, who was going to be doing work on cogeneration.

Because of—we did, as Mr. Wampler mentioned before, build milestones into these projects, as we did with our gas turbines program, to enable us to make decisions on whether or not to proceed from phase to phase with these projects.

We'll be in a position later this year to decide whether or not those two projects should go forward, and it's our anticipation, based upon the funding that we requested in the 1989 budget, that one of those two projects would go forward to future phases.

Mr. BOUCHER. All right. Thank you very much. I appreciate that answer. I would simply like to stress to you my personal support for funding in this area, and I'll tell you now that it is my intention to offer an amendment which would restore funding for the upcoming fiscal year at least to the level for the current fiscal year in that category.

The other point I would like to make is that I very much endorse the comments of the gentleman from Pennsylvania with respect to the need to have an adequate level of funding for the Coal Preparation category, and I would very much hope that in the next round of project awards under the Clean Coal Technology Reserve that you would find it appropriate to provide an award for one or more coal preparation projects.

In the 12—I think it is—awards that have been issued so far, we do not see any of those having been awarded to coal preparation projects. I know that you've had a number of submittals in that area. I'm confident that you will have coal preparation proposals before you in the second round, and I would very much hope that you would view those favorably and that we would find one or more of those among your awards. Do you want to comment on that?

Mr. WAMPLER. Yes. We, too, hope that we have a good number of coal preparation proposals for Clean Coal Round Number 2. We've been very, very careful in setting up the program criteria for the whole Clean Coal Program Round 2 to ensure the coal preparation is eligible to be involved in this funding in these projects. So we hope that we'll get a number of good proposals for coal preparation.

Mr. BOUCHER. Okay. Those are the only questions that I have.

Mr. Shays.

Mr. SHAYS. No questions, Mr. Chairman.

Mr. BOUCHER. Mr. Stallings.

Mr. STALLINGS. I have no questions. Thank you.

Mr. BOUCHER. All right. I believe that concludes our questions of this panel. The record of this hearing will remain open for the purpose of additional questions being submitted to you and also for the purpose of filing your answers.

Gentlemen, we appreciate very much your being with us today.

Mr. WAMPLER. Thank you, Mr. Chairman.

[Questions and answers for the record follow:]

Department of Energy
Washington, DC 20585

May 6, 1988

Honorable Marilyn Lloyd
Chairman
Subcommittee on Energy Research
  and Development
Committee on Science, Space, and Technology
House of Representatives
Washington, D.C. 20515

Dear Madam Chairman:

On March 2, 1988, J. Allen Wampler, Assistant Secretary for Fossil Energy appeared before your subcommittee to discuss the Department's Fiscal Year 1989 budget authorizaton for Fossil Energy.

Following the hearing, you submitted written questions for our response to supplement the record. Enclosed are the answers to those questions, which also have been sent to the committee staff.

If you have any questions, please have your staff call Rebecca Thompson on 586-4277. She will be happy to assist.

Sincerely,

Rebecca R. Thompson
for Robert G. Rabben
Assistant General Counsel
  for Legislation

Enclosures

Celebrating the U.S. Constitution Bicentennial — 1787-1987

POST-HEARING QUESTIONS AND ANSWERS

FROM THE MARCH 2, 1988,

HEARING

BEFORE THE

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT

WITNESS: J. ALLEN WAMPLER

ASSISTANT SECRETARY

FOR

FOSSIL ENERGY

QUESTIONS FROM THE COMMITTEE

Coal

Question: The United States has made good progress on the implementation of our portion of the $5 billion agreement on acid rain. Please describe what the Canadian government agreed to in the acid rain agreement. What is the status of their implementation of the agreement? How much money have they allocated to date?

Answer: The Canadian commitments resulting from their acceptance of the recommendations of the Special Envoys on Acid Rain are:

- to continue to keep acid rain high on the agenda in meetings between the Heads of State,
- to participate in a consultative group of diplomatic and environmental officials with the United States,
- to pursue, "through combined efforts" with the U.S., research on six specific topics,
- to review existing legislation for opportunities to reduce emissions,
- to inform the U.S. of intended changes in relevant laws and regulations, and
- to share results of the Canadian technology development program (smelter research) with the United States.

The degree to which each of these commitments has been met, has been discussed with U.S. officials in meetings of the bilateral consultative group. Funding associated with these programs would be only administrative in nature.

There are no new emissions reductions or new controls development programs added as a Canadian obligation due to this effort.

Prior to the study undertaken by consultations of the Special Envoys, Canada, in 1985, announced an Acid Rain Control Program which contained a number of SO_2 control actions that had been proposed from 1982 to 1985, plus some new elements including adoption of U.S. motor vehicle standards for new vehicles beginning in 1987/1988. Canada's commitment to SO_2 emissions reductions in the seven eastern provinces involves an announced 50% reduction from 1980 eastern Canada emissions. If the announced goal is fully met, actual emissions would be reduced only 41% from actual 1980 emissions levels in these provinces, however, Canadian emissions reductions are allocated, by federal-provincial agreements, among the seven eastern provinces (see Table 1). Earlier this year, the seventh provincial agreement was completed; several agreements had been completed in 1986. If met, the allocated emissions reduction requirement would provide at least a 35% SO_2 emission reduction from the actual 1980 emissions occurring in the eastern provinces. Of the seven provinces, four provinces (Ontario, Quebec, New Brunswick and Newfoundland) are required by 1994 to reduce emissions below the actual 1980 emissions level, while the other three provinces are subject to caps on allowed growth of emissions at or above the actual 1980 provincial level.

Other elements of the 1985 Canadian program include:

- $25 million for controls research for smelters,
- $150 million cost-sharing with provinces and industries for implementation of new control techniques, and
- $30 million for effects-related research and monitoring.

All of these elements of the 1985 Canadian Acid Rain Program are described by Canadian Federal officials as progressing and are at least on schedule.

E-21

SULPHUR DIOXIDE EMISSION TARGETS UNDER THE CANADIAN ACID RAIN PROGRAM

PROVINCE	1980 Actual (000 Tonnes)	1994 Target (000 Tonnes)	Reduction from 1980 Actual (000 Tonnes)	Reduction from 1980 Actual (Percent)
Manitoba	484	550	+ 66	+13.6%
Ontario	1,772	885	-887	-50.1%
Quebec	1,098	600[a]	-498	-45.4%
New Brunswick	220	185	- 35	-15.9%
PEI	5	5	0	.0%
Nova Scotia	193	204	+ 11	+ 5.7%
Newfoundland	56	45	- 11	-19.6%
TOTAL	3,815	2,474	- 1,341	-35.2%
STATED GOAL		2,300	-174[b]	

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a) Quebec's emission target is to be achieved by 1990.

b) This portion of the reductions has not been allocated to any province.

QUESTIONS FROM THE COMMITTEE

Coal Liquefaction

Question: The request for coal liquefaction activities, including both direct and indirect methods, have been substantially reduced. In particular, activities at facilities in La Porte, Texas, and Wilsonville, Alabama, are scheduled for close out. What did this research tell us about the economic feasibility of liquefaction techniques to provide liquid fuels to the marketplace?

Answer: Wilsonville has successfully demonstrated the operation and performance of the two-stage liquefaction process concept and has shown it to be a significant improvement over the single stage processes (H-Coal, EDS). Liquid yields per ton of coal have increased by over 30 percent, product quality is higher, and estimated capital costs per unit of product reduced by over 15 percent. As a result, estimated costs of coal liquids by direct liquefaction have been reduced by 28 percent compared to the single stage processes that have been demonstrated. As a result, the cost of liquid products has been reduced to $30 to $35 per barrel of oil equivalent. Implementation of further innovative steps that have been identified should result in reduction to a cost of $25 to $30.

At La Porte, upon completion of the currently scheduled Process Development Unit (PDU) operation and supporting research, a significant quantity of PDU and laboratory data will have been obtained for (1) synthesis of methanol in conjunction with an Integrated Gasification Combined Cycle and (2) all methanol production using a balanced synthesis gas input as a direct improvement to conventional methanol production technology. Available prior year funds are adequate to operate the La Porte facility through FY 1989.

With this technology data base, industry can then make investment decisions regarding possible additional investigation and subsequent scale-up development.

QUESTIONS FROM THE COMMITTEE

Coal Liquefaction

Question: What liquefaction schemes are ready to become commercialized? If any, please tell us which industrial players are commercializing these technologies.

Answer: At present, none of these more advanced technologies appear to be ready. However, as part of the Clean Coal Initiative, Ohio-Ontario Fuels plans to produce a liquid fuel, by the co-processing route, as a refinery feed. Also, Tennessee Eastman is producing methanol from coal via indirect liquefaction as an intermediate to making acetic anhydride at a commercial facility in Tennessee.

QUESTIONS FROM THE COMMITTEE

Coal Liquefaction

Question: If commercialization prospects are dim, in your opinion, how much more research is needed to bring the most promising liquefaction process to an economically competitive level?

Answer: Though commercialization prospects for coal liquefaction are unfavorable in the very near term, coal-derived liquids remain the leading option for relieving the U.S. domestic oil supply shortfall, which is expected in the 1990's. A focused research and development program could reduce the cost of producing liquids from coal to the range of $25 to $30 per barrel of oil equivalent. This advanced technology could be commercialized during the 1995-2000 time period, when world oil prices are projected to rise to this level.

QUESTIONS FROM THE COMMITTEE

Underground Coal Gasification

Question: What is the status of the Underground Coal Gasification project?

Are there any plans for future underground coal gasification projects?

Is there a need to test eastern coals?

Answer: The Rocky Mountain 1 Underground Coal Gasification (UCG) project just completed 102 days (as of February 27, 1988) of a successful burn. Aquifer contamination control procedures were initiated on February 28, 1988, and are expected to last between 60 and 200 days. This will be followed by 5 years of aquifer monitoring. This project will help to transfer to industry UCG technology in flat lying subbituminous coal seams. A previous test at Rawlins, Wyoming, successfully transferred technology for steeply dipping coal seams. This is the kind of project recently selected for participation in the Clean Coal Program. There are no plans for future R&D projects, nor for testing eastern coals. However, in FY 1989 we will be analyzing previous test data for application to eastern coals.

QUESTIONS FROM THE COMMITTEE

Magnetohydrodynamics

Question: The Department claims that continued MHD development is too expensive. Please tell us how much the Federal Government has invested in MHD development.

Answer: The Department has invested on the order of $600 million, over a period spanning a decade or more, on MHD research and development. It is estimated that $172 million would be required over a five year period, starting in FY 1988, to demonstrate the MHD proof-of-concept (POC) applicable to large-scale power generation. This is judged to be too costly and unaffordable for the Department to pursue.

QUESTIONS FROM THE COMMITTEE

Magnetohydrodynamics

Question: **In the budget book justification for MHD, you state you are participating in the first year of a five-year program. How do you intend to fund the remaining four years of the contract?**

Answer: The Department has been pursuing the development of MHD in response to Congressional direction to implement the MHD program plan submitted to the Congress in June 1984. The implementation of that program required the competitive award of R&D contracts for demonstrating the MHD proof-of-concept (POC). The first year of the POC program was FY 1988. The full five year effort would require $137 million beyond FY 1988 to complete (or a total of $172 million for the five year period FY 1988-FY 1992). This is judged to be too costly and unaffordable to pursue. As a result the Department is not proposing to continue funding the MHD program.

QUESTIONS FROM THE COMMITTEE

Magnetohydrodynamics

Question: What happened to the MHD program plan?

Answer: An FY 1988 MHD program plan, describing the five year proof-ofconcept program, has been prepared and is undergoing review by the Department and other agencies. It is expected that a final version should be available by the end of April 1988.

QUESTIONS FROM THE COMMITTEE

Magnetohydrodynamics

Question: What is the status of the Italian/US MHD agreement?

Answer: There exists a U.S./Italian fossil energy agreement which allows for cooperation in MHD. The Italian government is currently sponsoring studies on a gas-fired MHD plant retrofit and a coal-fired MHD pilot plant. Preliminary findings are expected to be released in the early part of 1988 and the Italian government is expected to make a decision on whether and how to proceed with a program within three months of the release of these findings. Prospective cooperative activities in MHD are being explored.

QUESTIONS FROM THE COMMITTEE

Magnetohydrodynamics

Question: What are the prospects of international cost-sharing?

Answer: There are several countries including Italy, Japan, and China, which are interested in prospective cooperative activities with the U.S., and these prospects are currently being explored. Existing bilateral agreements in fossil energy research between the U.S. and these countries could serve as the mechanism for implementing specific cooperative activities in MHD. These activities could include some form of cost-sharing, either in whole or in part, depending on potential mutual benefits, common interests, and compatibility of the respective national program objectives, approaches, and schedules.

QUESTIONS FROM THE COMMITTEE

Fuel Cells

Question: To your knowledge, have any orders been placed for phosphoric acid fuel cells?

Answer: The 200 kW on-site powerplant market entry program, sponsored by IFC and GRI, has been quite successful. It is reported that IFC has received commitments from some gas utility companies and is negotiating sales for over sixty 200 kW powerplants.

The 11 MW PAFC electric utility powerplant commercialization program, sponsored by EPRI and IFC, has not been successful. No domestic electric utility sales have occurred. However, IFC has been negotiating sales with companies in Japan and Italy. A utility company in Japan has purchased twenty stacks for a single 11 MW powerplant, and sales of a small number of additional units are under negotiation with a purchaser from Italy.

QUESTIONS FROM THE COMMITTEE

Fuel Cells

Question: If not, what is the DOE estimate for funds required to market this technology so that commercial orders are placed?

Answer: The Department believes that a modest R&D program could provide efficiency and cost improvements that could, if coupled with private sector demonstration activities, significantly improve the competitive position of phosphoric acid fuel cell systems. The Department's fiscal year 1988 phosphoric acid fuel cell budget, together with prior year carryover funds, will provide the needed R&D and further advance the technology.

QUESTIONS FROM THE COMMITTEE

Surface Coal Gasification

Question: What is the status of Waltz Mill and Schenectady?

Answer: The Waltz Mill contract, which will expire on September 30, 1988, has been modified using $4.3 million of FY 1988 appropriations. The modifications will permit a series of tests to be conducted to provide a better definition of process performance parameters for the integrated gasifier/hot gas cleanup technology. Upon completion of the tests, the "proof-of-concept" development will be complete because the technical feasibility of this technology has been established. Fossil Energy negotiated, in the contract modification, close out of the Waltz Mill Gasification/Hot Gas Cleanup Test Facility. There will be no additional cost to the Government for disposal of the Government-owned equipment beyond the funds presently being obligated to the contract.

The GE Schenectady contract has been signed with a total obligation to date of $4.9 million. The GE design for a hot moving-bed zinc ferrite desulfurization test facility has been reviewed and approved by METC, as has the program work plan. Several technical issues were identified by METC on the operability of the system. These issues were subsequently resolved by GE prior to METC approval to proceed. Site preparation and procurement of long lead items have been initiated.

QUESTIONS FROM THE COMMITTEE

Surface Coal Gasification

Question:	In what form have the research results from these projects been compiled for dissemination to industry in terms of "lessons learned" in gasification?
Answer:	Both projects produce quarterly and annual technical reports containing experimental data and evaluations of the results of the various test programs. Both contractors have presented papers reviewing the projects annually at the METC Gasification Projects Contractors Meeting. These papers are published annually in a Proceedings Publication and are available from the NTIS, U.S. Department of Commerce, as are the annual reports for the projects. The contractors also publish articles in trade magazines and have presented papers at the annual Pittsburgh Coal Conference and Washington Energy Technology Conference, as well as National AIChE and ASME meetings. The latest GE Report was published in late 1986 and the latest KRW Report in December 1987. Even more significantly, both contractors are moving aggressively to commercialize their technologies in gasification and cleanup at KRW and cleanup at GE. The KRW technology is being incorporated in the KRW CCT project. GE continues to offer its technology to system developers in the CCT and ICCT programs.

QUESTIONS FROM THE COMMITTEE

Enhanced Oil Recovery

Question: The Department has required level funding for the Enhanced Oil Recovery activities in the FY 1989 budget request. Please describe recent progress in accomplishments of the program.

Answer: The following describes some of the program accomplishments during the last five years:

- Successfully transferred the operation of the Bartlesville Energy Technology Center (BETC) to the private sector. The new research establishment is now known as the National Institute for Petroleum and Energy Research (NIPER) and is operated by the IIT Research Institute of Chicago, Illinois.

- Completed the cost-shared field test program involving almost all of the enhanced oil recovery (EOR) techniques such as polymer injection, surfactant flooding, alkaline injection, gas flooding, and thermal recovery techniques. Many of the test results were analyzed and results reported to the petroleum industry. Analysis of data indicated large gaps in current knowledge of EOR processes which have led us to concentrate more on the basic, fundamental research.

- Continued a program of fundamental research in chemical flooding techniques. Work at NIPER has resulted in the development of surfactants for profile modification and cross-linking technology for biopolymers in powdered form. These techniques allow for greater oil recovery from previously bypassed areas of the reservoir. Fundamental research is continuing at universities across the country in such important areas as surfactant-enhanced EOR, permeability modification with gelled polymers, adsorption numerical simulation of EOR processes, phase behavior, multiphase flow, etc.

o Conducted successful field pilot test of carbon dioxide injection process and developed the basic framework for a new nitrogen injection technique. The field pilot test met all expectations, production continues, and the field operator has decided to expand the project. In-house numerical simulation work at METC has resulted in the development of computer models that will permit application of sophisticated mathematical techniques to carbon dioxide flooding. Planning is under way for pilot field work to test a mobility control concept developed as a result of the basic research over the last three years.

o Initiated a field project in Louisiana to test the feasibility of cyclic injection of carbon dioxide for increasing the recovery of oil.

- Started new program of research on the use of microorganisms for EOR. Laboratory research is focused on screening of microbes and the assessment of environmental effects of microbial use. Several field tests are under way in Texas, Louisiana, and Oklahoma. A training course and symposium on MEOR was held. The course was designed for independent operators. Over a hundred people participated and indicated their willingness to follow up on the technology.

- Conducted basic research and laboratory-scale field tests in thermal recovery of heavy oil. Laboratory studies have shown extremely high recoveries of oil in place; however, field experience has shown bypassing of the oil, resulting in lower than expected production. Additive compounds have been screened and tested for use with steam and have been shown to be effective in preventing such bypassing.

- Initiated a cooperative effort with the State of Alaska to determine the feasibility of developing and testing novel EOR techniques using steam injection with carbon dioxide and hydrocarbon gases for the recovery of very large resources contained in the West Sak reservoirs.

- Completed a successful cooperative project with Venezuela on subsidence due to fluid withdrawal and initiated new work in geoscience covering the generation, migration, and accumulation of crude oil. International cooperation agreements in EOR research have been implemented with Canada, Mexico, UK, Italy, Norway and IEA.

QUESTIONS FROM THE COMMITTEE

Enhanced Oil Recovery

Question: Please give us the status of the extraction technologies, including your assessment of the most promising technologies.

Answer: Basically, there are three types of EOR technologies: chemical, gas displacement and thermal. Each has several variants which are in various stages of development.

Thermal recovery methods are most frequently used and contribute most of the oil produced by EOR -- 79% out of a total EOR production, which is 600,000 barrels per day. In this class, steam flooding and steam soak are most commonly used. Steam flooding is applicable largely to heavy oil reservoirs as it helps reduce oil viscosity so that it can flow more easily, within the reservoir, to a producing well. In situ combustion, also known as fireflooding, utilizes oxygen in the air to combust part of the oil in its natural setting and to displace the remainder into producing wells. The in situ combustion technology is significantly more energy efficient, but is not widely used because of severe problems encountered with the process control, corrosion, emulsion and safety, particularly when oxygen-enriched air is used.

Gas displacement methods are less common but growing in popularity and importance. At this time, about 16% of EOR production is attributable to gas flooding. In the past, natural gas was most often used in the "inmiscible" or "miscible" mode, but due to its increased value, it was largely replaced by carbon dioxide, flue gas and nitrogen. Gas flooding is commonly used in light oil reservoirs, particularly in carbonates of West Texas, where other methods cannot be easily used.

Chemical flooding is the most complicated and most expensive of all the EOR methods. In its simplest and most commonly used form it is known as polymer flooding. Polymer flooding relies on the addition of polymer to increase the viscosity of the displacing water and thereby slightly increasing oil recovery. The so called micellar-polymer method relies on the injection of certain surface active agents to displace oil in the "miscible" mode. Micellar-polymer technology has the potential of very high oil displacement and recovery but it is beset with problems ranging from cost of the chemicals to chemical degradation in the reservoir due to elevated temperatures, high water salinity and the unwanted chemical-rock reactions. Only about 5% of the EOR oil is produced via chemical means, but its importance is growing.

The question of the most promising technologies will be addressed in terms of the short term and the long term.

In the short term, the most promising approach to higher oil recovery seems to be in better reservoir characterization, understanding of reservoir heterogeneities on fluid flow in those reservoirs and the development of diagnostic techniques to better identify reservoir heterogeneities. Referring to the latter, there exists an acute need for better methods of "interwell" reservoir characterization, including the distribution of porosity, permeability and fluid saturations on a spatial basis.

In the long term, significant technological improvements in the development of entirely new approaches to oil recovery are needed. Some of the most promising technologies include the application of foams, certain gels and other diverting agents to modify the injection profile and displace oil more uniformly and completely. Profile modification control and mobility control are perhaps the most important areas for further work. They are applicable equally to all types of EOR processes.

Other promising technologies include the earlier mentioned "interwell" reservoir characterization which is necessary for better process control and higher quality input into reservoir simulators. Recent improvements in microelectronics, high density and high speed data processing could be very helpful in promoting the acceptance of this technology. Finally, there are new concepts, such as microbial EOR, which could soon be applied to low cost stripper wells and eventually to certain classes of depleted oil fields.

QUESTIONS FROM THE COMMITTEE

Unconventional Gas Recovery

Question: What is the status of the $2.5 million that was appropriated in FY 1988 for a cooperative venture in secondary gas recovery? Assuming that a joint venture is forthcoming, is there money in the FY 1989 budget to continue this program and where in the budget does the request appear?

Answer: Both the Gas Research Institute and the Texas Bureau of Economic Geology have expressed an interest in a secondary gas recovery project. They are presently developing an unsolicited proposal for submission to DOE in April 1988. No money is requested for the FY 1989 budget for continuation of a secondary gas project.

QUESTIONS FROM THE COMMITTEE

Geoscience

Question: Please give us a status report on the Department's plan to implement the Office of Geoscience Research.

Answer: The Office of Geoscience Research was established in September of 1987, under the Assistant Secretary of Fossil Energy (ASFE). The staffing of the office has been initiated with the hiring of four people, including the Deputy Director. An intensive effort is currently underway to recruit the Director and other staff. It is anticipated that these positions will be fully staffed by late spring. Initial activities undertaken include reviewing Fossil Energy programs and proposals during the Department's FY 1989 budget process and holding the initial meeting of the Hydrocarbon Geoscience Research Coordinating Committee. In addition we are maintaining, and expanding, planned research in oil and gas extraction and are soliciting comments on the draft EOR Initiative that was developed by FE staff from outside sources and from the Department's newly created Hydrocarbon Geoscience Research Coordinating Committee.

We are in the process of implementing the $500,000 effort Congress authorized to obtain the outside expertise needed to develop the comprehensive strategic plan. As part of this effort, Fossil Energy intends to obtain the support of the Geoscience Institute for Oil and Gas Recovery Research, a consortium of state geological surveys and universities.

It is anticipated that this consortium will provide much of the information needed for an integrated broad-based and focused geoscience research plan. The input from all of the above activities, as well as others, will be used to formulate the overall draft integrated program plan.

QUESTIONS FROM THE COMMITTEE

Geoscience

Question: In your budget submission, you requested a reduction of 10 FTE's at Headquarters. How will this reduction affect efforts to fully staff the Office of Geoscience Research?

Answer: The proposed reduction of 10 FTE's in Fossil Energy Headquarters for FY 1989 will not affect the efforts to staff the Office of Geoscience. The current FTE allocations includes 2 FTE's in FY 1988 and 4 FTE's in FY 1989 for the Office of Geoscience Research. If additional FTE's are required in FY 1989, they will be provided from within the overall Fossil Energy allocation.

QUESTIONS FROM THE COMMITTEE

Geoscience

Question: When do you anticipate being fully staffed in the Office of Geoscience Research?

Answer: Four positions in the Office of Geoscience Research have already been filled, including that of the Deputy Director, a Physical Scientist, a Program Analyst and a Secretary. Applications for the position of Director have been received and are being reviewed. It is anticipated that this position will be filled by late spring to complete the staffing of the Office.

QUESTIONS FROM THE COMMITTEE

Geoscience

Question:	Do you intend to make the Office of Geoscience Research a budget line item?
Answer:	We do not intend to request a separate line item in the Fossil Energy R&D budget for the Office of Geoscience Research. The funding for these geoscience activities will continue to be requested in the individual technologies, e.g., Enhanced Oil Recovery, Unconventional Gas Recovery and Advanced Process Technology. For example, $500,000 was provided in the Underground Gas Recovery Program in FY 1988 for assistance in the development of a comprehensive geoscience program plan. In addition, some administrative support will be provided from the Program Direction account.

QUESTIONS FROM THE COMMITTEE

Geoscience

Question: How much do you anticipate spending on Geoscience Research in FY 1989?

Answer: We believe that the FY 1989 request reflects the kind of work to be funded and the degree to which Federal funds can effectively be used to resolve critical issues. Below is a table of requested budgets for FY 1989 by activity.

Geoscience Activity in the Petroleum and Gas Budgets
($ in millions)

Activity	FY 1989 Request
Advanced Process Technology	$ 1.016
Enhanced Oil Recovery	6.878
Unconventional Gas Recovery	1.068
Totals	$ 8.962

The Hydrocarbon Geoscience Research Coordinating Committee will ensure that the work in these activities is coordinated with, and does not duplicate, Geoscience efforts in Renewable Energy (Geothermal requested $3.21 million for Geoscience in FY 1989) and Energy Research (Basic Energy Sciences requested $15.58 million for Geoscience in FY 1989).

QUESTIONS FROM THE COMMITTEE

Geoscience

Question: When fully staffed, what do you anticipate your first activities will be?

Answer: The activities of the Office of Geoscience Research have already begun. The first activity has been to activate the Hydrocarbon Geoscience Research Coordinating Committee. The Committee met on February 26, 1988, and was given a copy of the Draft Enhanced Oil Recovery Initiative to review. It was also requested to recommend key activities and funding summaries for geoscience related research in FY 1988 and proposed for FY 1989.

In addition to the representative of concerned Department of Energy offices, the Committee includes a representative from the U.S. Geological Survey and the National Science Foundation as Ex-Officio members.

We are in the process of implementing the $500,000 effort Congress authorized to obtain the outside expertise needed to develop a comprehensive strategic plan for geoscience research. As part of this effort, Fossil Energy intends to obtain the support of the Geoscience Institute for Oil and Gas Recovery Research, a consortium of state geological surveys and universities.

It is anticipated that this consortium will provide much of the information needed for an integrated broad-based and focused geoscience research plan. The input from all of the above activities, as well as others, will be used to formulate the overall draft integrated program plan.

QUESTIONS FROM THE COMMITTEE

Facilities

Question: In the FY 1988 appropriated budget, $17.7 million was added for facility construction. What is the status of these construction projects, the total estimated costs and schedules to complete?

Answer: The status of the FY 1988 construction projects as of March 29, 1988 is as follows:

A. Energy Research Center (West Virginia University)

The DOE has received a formal grant application from the University, and thus will be able to negotiate a grant award after the required Congressional review period. The Department transmitted on March 8, 1988, in accordance with the Energy Reorganization Act of 1974, a formal notification to Congress of its intent to vest title to this facility in the University. The total estimated DOE cost of this construction project is expected to be $15 million of which $6.0 million is to be from FY 1988 funds.

B. Energy Research Center (University of Oklahoma)

The DOE has received a formal grant application from the University, and thus will be able to negotiate a grant award after the required Congressional review period. The Department transmitted on March 8, 1988, in accordance with the Energy Reorganization Act of 1974, a formal notification to Congress of its intent to vest title to this facility in the University. It is expected that the total estimated DOE cost of this construction project will be $9.0 million of which $5.5 million is to be from FY 1988 funds.

C. PETC Program Support Facility Renovation

The A&E work is being initiated in the 2nd quarter of FY 1988. The preliminary total estimated cost of the project is $5.238 million of which $.25 million of A&E work is funded from FY 1988 general plant project funds, as mandated by Congress.

D. METC Project Support Building

The A&E work has been completed. Construction will start the 3rd quarter of FY 1988 and be completed the 1st quarter of FY 1992. The preliminary total estimated cost of the project is $12.477 million of which $4.0 million is funded in FY 1988.

E. PETC Chemical Engineering Laboratories

The A&E work is being initiated in the 2nd quarter of FY 1988 and will continue through FY 1989. The total estimated cost of the project is $4.8 million of which $.25 million of A&E work is funded from FY 1988 general plant project funds as mandated by Congress.

INSERT FOR THE RECORD

Committee: Science, Space, and
Technology
Subcommittee: Energy Research
and Development
Date: March 2, 1988
Page 36
Line 839

FOSSIL ENERGY'S EFFORTS ON STUDIES REGARDING TECHNOLOGY EXPORT POTENTIAL

The following information contains FE's current efforts on studies regarding export potential of Fossil Energy R&D technologies. This includes a summary outline of Lesser Developed Countries (LDC) initiative and the first draft of "Potential Markets for Small Coal-Fired Combustors in OECD Countries Study."

Also, PETC is currently developing work on coal-water mixture programs for Korea and Puerto Rico. However, these studies are not yet available.

DOE/FE LDC INITIATIVE

March 3, 1988

OBJECTIVES: TO IDENTIFY, EVALUATE, ANALYZE, AND RECOMMEND MARKET OPPORTUNITIES FOR U.S. FOSSIL FUEL TECHNOLOGIES FOR POWER GENERATION AND/OR INDUSTRIAL UTILIZATION. TO SET STAGE FOR IN-DEPTH ANALYSES FOR FEASIBILITY STUDIES IN SELECTED COUNTRIES INVOLVING U.S. INDUSTRY.

ACTIVITIES:

- SCREEN, REVIEW, AND SELECT POTENTIAL CANDIDATE COUNTRIES.
- EVALUATE AND SELECT APPROPRIATE FE TECHNOLOGIES.
- REVIEW AND DISCUSS ALTERNATIVES WITH AID, DOE, AND ANL TEAM.
- PROFILE U.S. FIRMS MARKETING FE TECHNOLOGY/ SERVICES.
- MATCH COUNTRY AND TECHNOLOGY ASSESSMENTS.
- PREPARE PROJECT REPORT INCLUDING RECOMMENDATIONS LEADING TO DETAILED FEASIBILITY STUDIES AND DEMO PROJECTS.

DOE/FE LDC INITIATIVE

THE ULTIMATE GOAL IS TO ENHANCE COMPETITIVENESS OF U.S. FOSSIL ENERGY TECHNOLOGIES IN DEVELOPING COUNTRIES

- SYSTEMS DEMONSTRATION PROGRAM
- NEW MARKETS IN COUNTRIES WITH FAVORABLE CIRCUMSTANCES
- REPLICABILITY

DOE/FE LDC INITIATIVE

THE JOINT PROGRAM BUILDS UPON DOE/AID EXPERIENCE AND EXPERTISE

STRATEGIES:

- BUILD UPON DOE/FE WORK AS BASIS FOR INCREASED OPPORTUNITIES FOR APPLICATION OF U.S. TECHNOLOGY AND MANUFACTURING OR SERVICE INDUSTRY CAPABILITY
- BUILD UPON AID WORK AS BASIS FOR CONTINUED ENERGY DEVELOPMENT ACTIVITIES; INTEGRATE AID FIELD MISSIONS

DOE/FE LDC INITIATIVE

TIMING	RESULT
PHASE 1 JUNE 1987 – OCTOBER 1987	DOCUMENTATION AND JUSTIFICATION FOR FEASIBILITY STUDY RECOMMENDATIONS
PHASE 2 NOVEMBER 1987 – MAY 1988	FEASIBILITY STUDY OF SPECIFIC PROJECT PACKETS DELIVERED TO ASFE (CARIBBEAN, ASIA)
PHASE 3 JUNE 1988 – JULY 1988	INTERAGENCY COORDINATION; PUBLIC FORUM
PHASE 4 AUGUST 1988 – TBD	ENGINEERING DESIGN & DETAILED FEASIBILITY, PROJECT IMPLEMENTATION AND CONSTRUCTION OVERSIGHT

DOE/FE LDC INITIATIVE

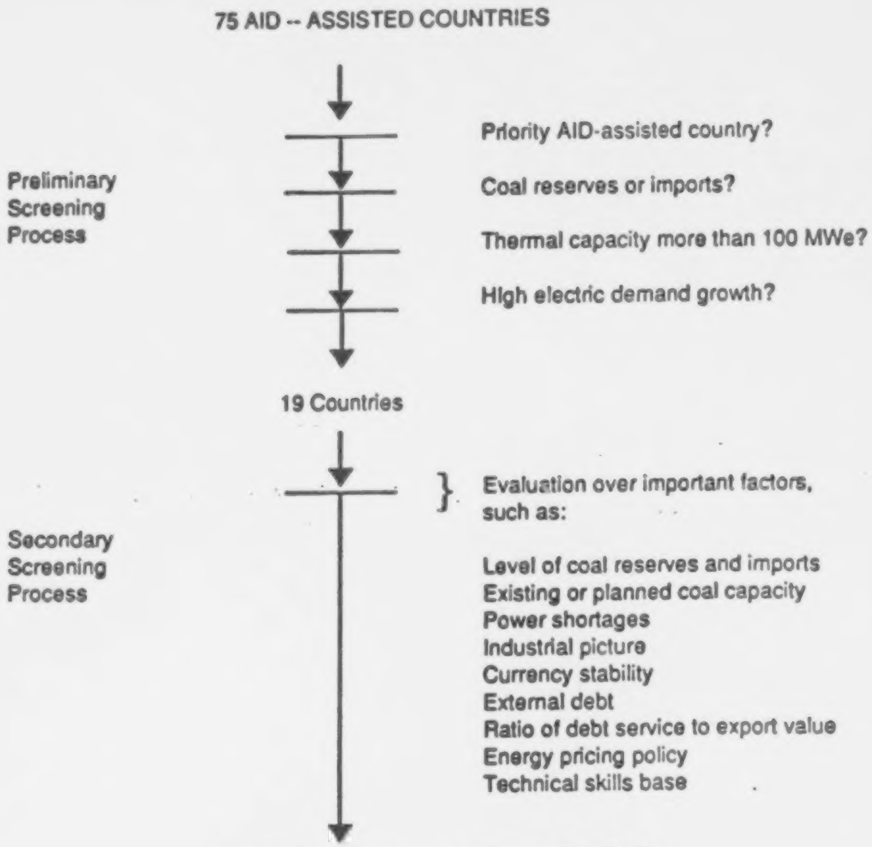
PHASE 1 WAS COMPRISED OF FOUR PRIMARY TASKS

- SCREEN POTENTIAL CANDIDATE COUNTRIES
- IDENTIFY LEADING FOSSIL FUEL TECHNOLOGIES
- PROFILE U.S. FOSSIL ENERGY COMPANIES
- COUNTRY/TECHNOLOGY SELECTIONS AND "ROAD MAP" FOR FEASIBILITY STUDIES AND PROJECT IMPLEMENTATION

RESULTS: IDENTIFICATION OF SELECTED COUNTRIES AND SPECIFIC TECHNOLOGIES OFFERING BEST POTENTIAL FOR SUCCESS.

DOE/FE LDC INITIATIVE

SUMMARY OF COUNTRY SCREENING PROCESS



75 AID -- ASSISTED COUNTRIES

Preliminary Screening Process

Priority AID-assisted country?

Coal reserves or imports?

Thermal capacity more than 100 MWe?

High electric demand growth?

19 Countries

Secondary Screening Process

Evaluation over important factors, such as:

Level of coal reserves and imports
Existing or planned coal capacity
Power shortages
Industrial picture
Currency stability
External debt
Ratio of debt service to export value
Energy pricing policy
Technical skills base

10 Countries Recommended For Further Study

Costa Rica	Jamaica
Dominicam Republic	Jordan
Ecuador	Pakistan
India	Philippines
Indonesia	Thailand

DOE/FE LDC INITIATIVE

PHASE 1 PRELIMINARY CANDIDATES

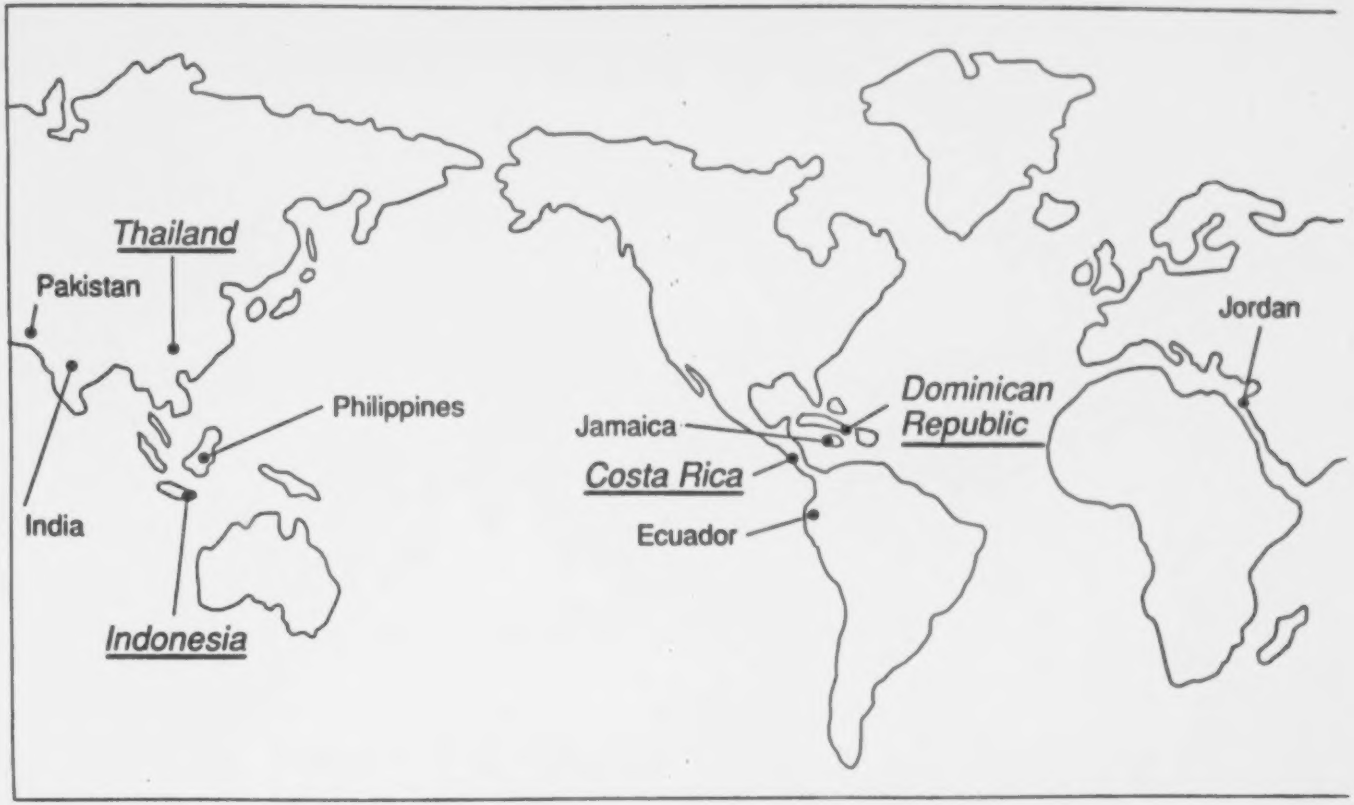
NEAR-EAST	ASIA	CARIB/L AMER
EGYPT	BANGLADESH	BOLIVIA
JORDAN	INDIA	COSTA RICA
MOROCCO	INDONESIA	DOMINICAN REPUBLIC
TUNISIA	PAKISTAN	EASTERN CARIB STATES
	PHILIPPINES	ECUADOR
	THAILAND	GUATEMALA
		HONDURAS
		JAMAICA
		PANAMA
		VENEZUELA

DOE/FE LDC INITIATIVE

FOUR COUNTRIES WERE RECOMMENDED FOR DETAILED PROJECT SYSTEM FEASIBILITY

CARIBBEAN/LATIN AMERICA	ASIA
COSTA RICA	INDONESIA
DOMINICAN REPUBLIC	THAILAND

DOE/FE LDC INITIATIVE


Thailand
Pakistan
India
Philippines
Indonesia
Jamaica
Costa Rica
Ecuador
Dominican Republic
Jordan

DOE/FE LDC INITIATIVE

TECHNOLOGY ANALYSIS

- FOSSIL FUEL TECHNOLOGIES
- APPLICABILITY FOR ELECTRIC POWER AND/OR INDUSTRIAL POWER SUPPLY NEEDS
- POTENTIAL FOR PROJECT DEMONSTRATION

DOE/FE LDC INITIATIVE

SCHEMATIC OF TECHNOLOGY SELECTION PROCESS

INITIAL SET OF TECHNOLOGIES

- Advanced Combustors
- Alternative Fuels
- Coal Preparation
- Fluidized Beds
- Fuel Cells
- Flue Gas Cleanup
- Heat Engines
- Coal Liquefaction
- MHD
- Surface Gasification

↓

GENERIC SCREENING

- State of technology development
- Technical expertise required
- Application to near term markets

↓

COUNTRY-SPECIFIC EVALUATIONS

↓

FINAL SET OF TECHNOLOGIES

- Advanced Combustors
- Alternative Fuels
- Coal Preparation
- Atmospheric Fluidized Beds
- Surface Gasification

DOE/FE LDC INITIATIVE

COUNTRY SPECIFIC TECHNOLOGIES

Country	Adv. Comb.	Fuels	Prep.	FBC	FGC	Liq.	Gas.
Costa Rica	P	P	P	P	-	-	S
Dominican Republic	S	S	P	P	-	-	-
Ecuador	S	S	-	P	-	-	-
India	S	S	P	P	S	S	S
Indonesia	P	P	P	P	S	-	S
Jamaica	S	S	-	P	-	-	-
Jordan	S	S	-	P	-	-	-
Pakistan	P	P	P	P	-	S	S
Philippines	P	P	P	P	-	S	S
Thailand	P	P	S	P	-	-	-

P: A Potential Primary Interest

S: A Potential Secondary Interest

-: Little or No Interest

DOE/FE LDC INITIATIVE

FIVE FOSSIL-FUEL TECHNOLOGIES WERE RECOMMENDED FOR PHASE 2

- **ADVANCED COMBUSTORS (Slagging Combustors)**
- **ALTERNATIVE FUELS (Coal-Water Mixtures)**
- **COAL PREPARATION**
- **ATMOSPHERIC FLUIDIZED BEDS**
- **SURFACE GASIFICATION (Integrated Gasification Combined Cycle)**

DOE/FE LDC INITIATIVE

VENDOR PROFILES

REVIEWED, ANALYZED, SCREENED U.S. COMPANIES FOR:

- SUBSTANTIAL CAPABILITIES/EXPERTISE IN THE FIVE SPECIFIC FOSSIL ENERGY TECHNOLOGIES.
- INVESTMENT INTERESTS
- EXPERIENCE IN DEVELOPING COUNTRIES.

DOE/FE LDC INITIATIVE

VENDOR PROFILE PROCESS

- IDENTIFICATION OF COMPANIES
    - DATA BASE SEARCHES
    - TRADE JOURNALS
    - CONFERENCE PROCEEDINGS
    - DOE REPORTS AND PUBLICATIONS
    - DOE CONTRACTOR REPORTS AND PUBLICATIONS

- DIRECT CONTRACT WITH IDENTIFIED COMPANIES
    - OBTAIN CURRENT INFORMATION
    - DETERMINE INTEREST

- VENDOR PROFILES PREPARED
    - TYPE OF TECHNOLOGY
    - TYPE OF SERVICES COMPANY OFFERS
    - LIST OF FUELS THE TECHNOLOGY USES
    - LIST OF TECHNOLOGY APPLICATIONS, ESPECIALLY INTERNATIONAL EXPERIENCE
    - OPERATING EXPERIENCE WITH THE TECHNOLOGY
    - CORPORATE AFFILIATION AND HISTORY
    - COMPANY INTEREST IN THE DOE/AID EFFORT

DOE/FE LDC INITIATIVE

ADVANCED COMBUSTORS & IGCC COMPANIES PROFILED

ADVANCED COMBUSTORS

U.S. Company -- U.S. Technology

AVCO Everett Research Laboratory
Babcock & Wilcox
Coal Tech
Foster Wheeler
Rockwell
TRW

INTEGRATED COAL GASISIFICATION COMBINED CYCLE

U.S. Company -- U.S. Technology

Allis-Chalmers
Dow Chemical
Kellogg Rust-Westinghouse (KRW)
Texaco

U.S. Company -- Foreign Technology

Shell

Foreign Company -- Foreign Technology

British Gas Corporation/Lurgi

DOE/FE LDC INITIATIVE

COAL-WATER MIXTURES & COAL BENEFICIATION COMPANIES PROFILED

U.S. Company -- U.S. Technology

Advanced Fuel Technology
Atlantic Research Corporation
Babcock & Wilcox
British Petroleum
Coaliquid, Inc.
Combustion Engineering
Jim Walters Resources
OXCE Fuel Company
Slurrytech Inc.
Standard Havens Research
TRW
United Coal Co.

U.S. Company -- Foreign Technology

Foster Wheeler Corp.
U.S. Fluidcarbon

Foreign Company -- Foreign Technology

Snamprogetti

Archictecture/Engineering/Construction/Consulting Firms

Bechtel Power Company
Burns & Roe
Stone & Webster Engineering
Stearns Roger Division, United Engineers & Constructors

DOE/FE LDC INITIATIVE

AFBCS - COMPANIES PROFILED

U.S. Company – U.S. Technology

Babcock & Wilcox
Combustion Engineering
Combustion Power Company
Energy Products of Idaho
Fluidyne Engineering
Foster Wheeler
Keeler Dorr-Oliver
Power Recovery Systems
Riley Stoker
Struthers Thermo-Flood
Wormser Engineering

U.S. Company – Foreign Technology

Pyropower Corporation
Stone Johnston Boiler Co.
Tampella Power Machinery

Foreign Company – U.S. Technology

Snamprogetti

Foreign Company – Foreign Technology

Cockerill Mechanical Industries
Fives-Cail Babcock
Sulzer Brothers

Architecture/Engineering/Construction/Consulting Firms

Bechtel Power Corporation
Burns & McDonnell
Burns & Roe
Fluor Daniel
Stearns-Roger Division, United Engineers & Constructors
Stone & Webster Engineering Corporation

DOE/FE LDC INITIATIVE

PHASE 2 CONSISTS OF SIX PRIMARY TASKS

- PERFORM DETAILED MARKET ANALYSIS FOR EACH COUNTRY SELECTED
- PRESENT DEVELOPING OPTIONS TO POTENTIAL PARTICIPANT GROUPS
- DETERMINE/DEVELOP IN-COUNTRY PROJECT SUPPORT
- PERFORM DETAILED PROJECT FEASIBILITY STUDY FOR EACH SELECTED COUNTRY
- MONITOR, PROMOTE, FOSTER LDC/U.S. GOVERNMENT/PRIVATE INDUSTRY SUPPORT
- DEVELOP PACKAGE CONTAINING BACKGROUND ON COUNTRY OPTIONS, TECHNOLOGY OPTIONS AND PROJECT OPPORTUNITIES

DOE/FE LDC INITIATIVE

PHASE 2 - ANTICIPATED RESULTS

IDENTIFICATION OF ONE FOSSIL ENERGY PROJECT IN EACH COUNTRY AND PACKAGE INFORMATION FOR PHASE 3 EFFORT

DOE/FE LDC INITIATIVE

PHASE 3 - INTERAGENCY COORDINATION & PUBLIC FORUM

- ASFE DELIVERS PACKETS TO PERTINENT AGENCIES, I.E. DOC, USTR, OPIC
- ASFE PRESENTS PACKETS TO VENDORS AT PUBLIC FORUM

ANTICIPATED RESULTS:

EFFICIENT AND EFFECTIVE DELIVERY OF PROJECT OPPORTUNITIES

DOE/FE LDC INITIATIVE

PHASE 4 - ENGINEERING DESIGN & PROJECT FEASIBILITY, PROJECT IMPLEMENTATION/CONSTRUCTION

- ASFE PROVIDES SUPPORT TO VENDORS FOR PROJECT DEVELOPMENT AS NEEDED

DOE/FE LDC INITIATIVE

DESIRED FINAL PRODUCT

- U.S.-DESIGNED AND U.S.-BUILT FACILITIES
- INCORPORATING U.S. FOSSIL ENERGY TECHNOLOGY AND PRODUCT
- BUILT BY U.S. VENDORS OR A U.S./LDC JOINT VENTURE
- FINANCED BY INTERNATIONAL BANKING COMMUNITY AND/OR OTHER PRIVATE SOURCES

ARGONNE NATIONAL LABORATORY
9700 South Cass Avenue, Argonne, Illinois 60439

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Arlington, Virginia 22209
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February 22, 1988

Ms. Denise Swink
Office of Clean Coal, Combustion
and Conversion Systems
U.S. Department of Energy
FE-20-GTN
Washington, D.C. 20545

Dear Denise:

Enclosed is a draft of the report entitled, "Potential Markets for Small Coal-Fired Combustors in OECD Countries: Country Screening Task." This interim report represents the product of Subtask 3 (FWP 49721).

This report has not been fully edited by the ANL editing staff and therefore undoubtedly contains some typographical and grammatical errors and format inconsistencies. It is also undergoing additional technical review. However, we did not want to further delay sending it to you. We will be updating the report as you review it.

Sincerely,

Marylynn Placet

cc: D. Streets
G. Dials
C. Szpunar

U.S. Department of Energy The University of Chicago

ARGONNE NATIONAL LABORATORY
9700 South Cass Avenue, Argonne, Illinois 69439

DRAFT - DO NOT CITE

POTENTIAL MARKETS FOR SMALL COAL-FIRED COMBUSTORS IN OECD COUNTRIES: Country Screening Task

by

M. Placet, L. Kenkeremath, D. Streets, D. Kern

February 1988

worked sponsored by

U.S. DEPARTMENT OF ENERGY
Assistant Secretary for Fossil Energy

POTENTIAL MARKETS FOR SMALL COAL-FIRED COMBUSTORS IN OECD COUNTRIES:

Country Screening Task

definition
"small coal fired
combustor"

by

M. Placet, L. Kenkeremath,
D. Streets, D. Kern

1 INTRODUCTION

This report describes a methodology to evaluate potential foreign export markets for U.S.-developed advanced coal-combustion technology for use in residential-commercial and light-industrial applications. The analysis focuses on characterizing the countries according to such factors as: historical and projected energy use patterns in various economic sectors; fuel availability and fuel use infrastructure; trade and competition factors affecting potential use of U.S. technology; environmental regulatory climate; and prevailing disposition toward or against increased coal use in each country considered. The analysis was used as the basis for selection of three countries for a further detailed study that will involve the gathering of facility-specific data and on-site interviews with energy decision makers.

The twenty-four developed countries that are members of the Organization for Economic Cooperation and Development (OECD) were selected as the set of countries to undergo the market-potential screening analysis. The criteria upon which the assessment is based are therefore oriented toward factors influencing energy choices is the OECD countries. Information about government energy policy and data on historical and projected energy use patterns are readily available for these countries, facilitating the analysis. Furthermore, trade relations between the United States and the OECD countries are well established; therefore, penetration of the markets in these countries could be viewed as less problematic than penetration of markets in less-developed or centrally-planned economies, where institutional barriers to trade and lack of technology-transfer mechanisms might exist.

This is not to say that the OECD countries are thought to represent the largest foreign market for U.S. advanced coal-combustion technology. Use of the screening methodology to examine coal-use potential in the OECD countries represents the first application of the methodology. However, with minor modifications to the factors chosen and the data-gathering techniques employed, the methodology could be applied to examine developing or newly-industrializing countries, which may prove to have higher overall potential for increased U.S. exports, due to the large increase in energy demand usually associated with development and industrialization.

2 METHODOLOGY

Since estimates of current energy use can serve to indicate the potential size of the replacement/retrofit market, and projections of future energy use may indicate the size of the potential market for new coal-fired combustors, the first step in the country screening process was to eliminate countries with low current or projected energy use in the residential, commercial and industrial sectors. Although small markets for advanced coal technology may exist in those countries characterized by low current or projected energy demand, the focus of the screening task was to choose markets where the potential appears large.

Table 1 shows the OECD countries and their current (1985) and projected (2000) residential/commercial/industrial energy use. The initial screening involved elimination of any country that does not have either total energy use in these sectors greater than or equal to 25 million tonnes of coal equivalent (Mtce) in 1985 or a projected increase in energy use in these sectors greater than or equal to 5 Mtce between 1985 and 2000. These requirements eliminate eight countries in which market potential is low. Table 1 identifies the fifteen countries for which more detailed examination was carried out in the next phase of the screening process.

The remainder of the screening methodology focused on analysis of eight important factors that would tend to increase the propensity of a country to import U.S. advanced coal-combustion technology for use in the residential, commercial, and industrial sectors. Three of the eight factors deal with the general energy situation in the country, as follows:

- Factor 1: The extent to which the national energy plan of the country favors coal use and to which coal is currently available in the country (via imports or production within the country).
- Factor 2: The degree to which the country is dependent on imported oil (especially oil imported from OPEC countries) or, to a lesser extent, natural gas imported from the U.S.S.R..
- Factor 3: Past or present experience with coal use and coal handling/transport in the country.

The following two factors are related to the prospects for increased small-combustor energy demand:

- Factor 4 High and/or increasing total energy use and/or coal share in the residential/commercial sector.
- Factor 5. High and/or increasing total energy use and/or coal share in the industrial sector.

Table 1. Current and Projected Industrial, Residential, and Commercial Energy Use in the OECD countries

		1985 I,R,C Energy Use (Mtce)	2000 I,R,C Energy Use (Mtce)	1985-2000 Growth (Mtce)
Australia	*#	46.1	65.7	19.6
Austria		22.3	24.3	2.0
Belgium	*	37.3	37.1	-0.2
Canada	*#	159.6	210.0	50.4
Denmark		16.0	17.9	1.9
Finland	*#[1]	23.7	28.4	4.7
France	*	141.6	141.5	-0.1
FRG	*	218.9	216.3	-2.6
Greece	#	11.6	17.5	5.9
Iceland		0.7	1.1	0.4
Ireland		7.1	8.4	1.3
Italy	*#	110.9	125.4	14.5
Japan	*#	275.7	363.0	87.3
Luxembourg		3.5	4.8	1.3
Netherlands	*	59.9	56.4	-3.5
New Zealand		8.5	9.8	1.3
Norway		20.2	23.6	3.4
Portugal	#	9.6	16.1	6.5
Spain	*#	48.0	66.9	18.9
Sweden	*	38.7	40.1	1.4
Switzerland		19.0	22.5	3.5
Turkey	*#	35.4	94.3	58.9
UK	*#	147.0	154.8	7.8
USA[2]	*#	1194.5	1494.3	299.8

---

* > 25 Mtce energy use in 1985.
# > 5 Mtce increase between 1985 and 2000.

[1] Because Finland fell just below the required level for both current and projected energy use, it will remain among the countries to undergo further screening.

[2] Shown for comparison only.

Note: Mtce = million tonnes of coal equivalent = approx. 28 x 10^{12} Btu.

Source: Coal Information 1987, OECD.

Two factors deal with trade incentives between the United States and OECD countries, as follows:

- Factor 6. High current level of trade between the U.S. and the country, and the degree to which incentives to increase trade, especially trade related to energy technology, exist.
- Factor 7. Absence of domestic suppliers of advanced coal technology in the country.

The final factor deals with environmental issues:

- Factor 8: Environmental pressure for advanced clean-coal-combustion technology.

Each country was given one of four ratings -- high, medium-high, low-medium, and low -- for each of the eight factors. (High ratings indicate favorable disposition toward increased coal use.) A list of questions was drawn up for each of the eight factors to guide the rating procedure. The answers to these questions are provided by statistical or other information relevant to the particular factor. Because all countries included in this analysis are members of OECD, a great deal of statistical energy information is available for them from various OECD publications.[1-10] This was supplemented with information from the U.S. Department of Commerce and other sources (primarily for the trade issues).[11-16] The information was compiled in tables, which can be found in the appendices to this report. (There is one appendix for each of the eight factors.) The ratings for all the countries for all the factors were then compiled in a matrix format. (The matrix with the country/factor ratings is included in this report in Section 3, "Results".)

The matrix, along with the data sheets that formed the basis for the ratings, were then used to segregate countries into three groups: (1) those with good potential markets for U.S. advanced small-combustor coal technology; (2) those with some potential, but for which some serious impediments exist (i.e., for which several low or low-medium ratings were given); and (3) those for which the potential market appears small, due to the presence of many impediments. Generally, to be categorized as having a "good potential market", a country was required to have high or medium-high ratings for most of the factors in all four of the factor categories (general energy situation, energy-demand growth, trade incentives, and environmental pressure).

Section 3 reports on how the fifteen countries were grouped into each of the three categories and why they were so grouped. That section also contains a general profile of each country that describes the conditions favoring or discouraging use of U.S.-developed advanced small-combustor coal technology.

It should be noted that a considerable amount of judgment was applied in the process of grouping the countries into the three categories as well as in rating the countries for each factor. The methodology does not employ a rigorous method such as decision analysis to weight the various factor ratings. However, during the rating process, some pieces of information influenced the ratings more than others. The remainder of this section explains this subjective weighting process. It also more fully describes the eight factors, lists the questions used to guide the rating procedure, and explains which questions most strongly influenced the final ratings.

2.1 FACTORS RELATED TO THE GENERAL ENERGY SITUATION

Factors 1, 2, and 3 are related to the general conditions influencing energy choices in the OECD countries. All three of the factors indicate whether or not the country is disposed toward increased coal use, but each factor looks at a different aspect of the energy situation in the country.

2.1.1 Factor 1: Energy Plan/Situation

The energy strategy of a country, as described in its government's energy plan, is one of the most important factors affecting the likelihood of increased coal use in that country. Some, but not all, of the energy plans of the OECD countries explicitly state that increased coal use is a primary goal. In many countries, reliance on indigenous energy resources is stressed in the energy plan; therefore, coal would be emphasized primarily if it is produced in those countries. Current reliance on and a desire for growth in production of nuclear energy would tend to promote electricity rather than coal use in the consuming sectors. On the other hand, the willingness of a country to import coal can be viewed as an indication of its commitment to coal use. Additionally, reduced imports from certain coal-supplying countries (e.g., South Africa and Poland) to OECD countries may occur in the future. A high current level of imports from such countries may indicate a potential U.S. opportunity to export coal and advanced coal-combustion technology as a package. Government actions to subsidize production of or to tax certain fuels also demonstrate a desire to promote or discourage the use of those fuels.

The answers to the following questions guided the country ratings for Factor 1:

- Does the energy plan of the country explicitly state that increased coal use is the primary goal?

- Is coal produced in the country? How much was produced in 1985?

- What percent of non-metallurgical coal use is supplied by indigenous sources?

- By what percent has coal production been increasing (or decreasing) over the last decade?

- Is the country currently reliant on any "exotic" form of energy (e.g., solar, peat, geothermal, hydroelectric, including energy used in the production of electricity that supplies the residential, commercial, or industrial sectors)? Are any of these indigenous "exotic" sources being heavily promoted in the energy plan?

- What percent of the country's electricity is generated by nuclear power? By what percent is nuclear power projected to grow between 1985 and 2000? For those countries with high nuclear generation, what percent of total residential/commercial/industrial energy use is currently (1985) and is projected to be (in 2000) supplied by electricity?

- How much coal (in tonnes) was imported in 1985? What are the primary sources (countries) of coal imports?

- By what percent have coal imports been increasing over the last decade?

- Does the government alter in any way (e.g., via taxes or subsidies) the market price of any fuel?

The answers to these questions can be found in Appendix 1.

The country ratings for Factor 1 were influenced most strongly by the level of coal production or imports, the change in the level of production or imports over the last decade, and the attitude of the government toward increased coal use, as expressed in the energy plan. One element which could move a country's rating up or down on this factor slightly was the role of taxes or subsidies affecting coal. The presence of taxes on coal tended to lower a country's rating, whereas taxes on oil were seen as promoting coal use. The information on nuclear power was used primarily when the energy plan was not too explicit about goals for coal use; in such cases, projections of nuclear power growth were used to gauge whether the country was leaning more toward nuclear or coal in power plants, since industrial and residential/commercial coal use is more likely to occur in countries that are committed to coal in the electric power sector. Whether or not the country imports coal from South Africa influenced the ratings very slightly in the upward direction.

2.1.2 Factor 2: Oil/Gas Import Dependency

The energy plans of almost all OECD countries call for reduced use of oil imports for national security reasons. A high level of oil imports, especially from OPEC countries, can therefore be viewed as an incentive to promote coal use. (The oil supply from OPEC may be viewed as more interruptible than supplies from other countries, such as OECD countries.) Additionally, dependence on gas imported from the U.S.S.R. may prove to be a factor in future decisions to increase coal use, since the availability of gas from the U.S.S.R. may decline in the future, as that country increases its own use of gas due to increased internal production and population growth. Price considerations aside, this factor therefore provides an indicator of the likelihood of coal-based technology substituting for oil and gas in the residential/commercial/industrial sectors.

The following questions guided the country ratings for Factor 2:

- What percent of the total primary energy requirement was supplied by imported oil over the last decade?
- What are the principal supplying countries for the oil imports?
- What percent of total primary energy requirement was supplied by natural gas from the U.S.S.R. over the last decade? What percent of total natural gas use was imported from the U.S.S.R. in 1985?
- Does the country have an indigenous oil and/or gas supply?

The answers to these questions are found in Appendix 2.

The country ratings for Factor 2 were most heavily influenced by the percentage of the country's total primary energy requirement (TPER) supplied by imported oil and whether or not the source of the oil was OPEC. High imports of gas from the U.S.S.R. factored less strongly toward a high rating, especially if the country has a strong relationship with the U.S.S.R. (e.g., in the case of Finland). One element which moved a country toward a lower rating for Factor 2 was the existence of an indigenous oil and/or gas supply.

2.1.3 Factor 3: Coal Experience

Increased use of coal is more likely in countries that have had some previous experience with coal and coal handling. Although power plant use of coal is not explicitly being examined in this study, a recent trend toward conversion of power plants to coal indicates both a commitment to coal and a lack of transportation and institutional constraints to coal use. In countries that use little or no coal or that have not shown some increase in coal use in recent years, the coal transportation infrastructure may be insufficient and attitudinal barriers to coal use might be present.

The following questions guided the ratings for Factor 3:

- What percent of total primary energy requirement of the country was supplied by coal over the last decade?
- How much energy consumed in the production of electricity was supplied by : a) coal; b) oil; c) nuclear -- over the last decade?
- What is the current capacity of coal-importing ports? Are additions to this capacity planned?
- Does a coal transportation infrastructure exist to transport coal to all major residential/commercial and industrial demand centers?

The answers to these questions can be found in Appendix 3.

The trend over the last decade in the use of coal as a percentage of the total primary energy requirement and the existence of an adequate infrastructure for coal transport were viewed as the most important aspects of Factor 3 in the rating procedure. A high current coal share and an increase in the coal share were seen as good indications of adequate coal handling experience and ability to increase coal use in the country (leading to high or medium-high ratings). Lack of adequate transportation infrastructure was seen as a fairly strong impediment and tended to move a country toward a lower rating. Coal's share of electricity production was weighted moderately strongly in the ratings.

2.2 FACTORS RELATED TO FUTURE ENERGY DEMAND

Residential/commercial energy demand projections and industrial energy demand projections were examined in Factors 4 and 5, respectively. In addition to analyzing energy projections, other factors (such as district-heating and combined-heat-and-power experience, demographic statistics, and types of industries in each country) were factored into the ratings.

2.2.1 Factor 4: Residential/Commercial Energy Demand

Increased coal use in the residential/commercial market could occur in several ways: 1) small coal-fired combustors might be increasingly used in institutional settings, multi-family housing, office buildings, large commercial operations (such as shopping malls), etc; 2) the use of district heating or combined heat and power (cogeneration) to supply heat and sometimes electricity to individual dwellings/buildings could become more widespread; and 3) coal/water slurry technology could be used to produce oil substitutes for use in any application that currently uses oil. These coal-combustion applications could occur in both retrofit (replacement) situations and new installations. Therefore, both the size of the current residential/commercial energy demand and the projected growth in that demand are important to the analysis of increased coal-use potential. The current ratio of oil to gas use is also an important factor, since coal can be viewed as a more likely substitute for oil than gas, especially in situations where the energy plan calls for reduced oil imports. Highly urbanized countries may be slightly more inclined to increase residential/commercial coal use, since coal distribution would be simplified by the concentrated demand and larger residential buildings would probably be present in highly-urbanized countries. Countries with current or planned use of district heating may also be more likely candidates for increased coal in the residential sector.

The following questions guided the rating procedure for Factor 4:

- o What was the total use of energy (including coal, oil, natural gas, electricity, and misc. sources) in the residential and commercial sectors (including agriculture) over the last decade?
- o What is the projected percentage per annum increase in population between 1985 and 2000?
- o What is the projected growth in energy use in the residential/commercial sector between 1985 and 2000?
- o What is the projected growth of coal use?
- o What was the percent of total res/comm energy use supplied by coal over the last decade? What percent of total res/comm energy use in 2000 is projected to be coal?
- o What is the current (1985) ratio of oil consumption to natural gas consumption in the res/comm sector?
- o What percent of the population lives in a) the largest city; b) cities of 500,000 or more; and c) other urban areas?
- o Is district heating currently practiced in the country? If yes, what is the installed district heating capacity and the percent of capacity that is coal-fired?

- Do institutional factors (including government policy goals) favor use of district heating or combined heat and power plants in the future?

The answers to these questions can be found in Appendix 4.

The element that most strongly influenced the ratings for Factor 4 was the projected growth in total energy demand in the residential/commercial sector, because energy demand growth is indicative of the number of new combustors that may be required in the future. Countries rated "high" for Factor 4 generally have high energy demand growth projections. Current energy demand carried somewhat less weight in the ratings than energy growth, since current demand represents the potential retrofit market, and replacement of existing combustors with new coal-fired ones is more problematic than installation of new combustors in "greenfield" sites.

A high current coal share of total demand had a fairly strong upward effect on the ratings, since it indicated that the country already had some experience with coal use in the residential/commercial sector. An increase in the coal share over the last decade also increased a country's rating, because it indicates a disposition toward increasing coal in the res/comm sector. A projected increase in the coal share also tended to move ratings upward. However, since the projections used in this analysis were made by the country governments, they are influenced by the biases for or against coal held by those governments. They are therefore reliable indicators of whether or not coal is being promoted by the government in the residential/commercial sector but do not generally consider the potential advantages advanced/innovative technologies have over conventional coal combustors. The availability of advanced technologies in the future could change the projections of coal use in the upward direction. Therefore, projections of the coal share did not influence the ratings for Factor 5 as much as the total energy demand growth and historical coal share did.

Coal-fired district heating experience generally moved ratings upward; several countries that were rated "low" for Factor 4 based on the answers to the other questions were increased to "low-medium" based on the district-heating question. A high degree of urbanization tended to influence the ratings very slightly in the upward direction.

2.2.2 Factor 5: Industrial Energy Demand

Advanced and innovative coal-combustion technologies may replace oil, natural gas, and electricity (via cogeneration) in the industrial sector. The level of current industrial energy use can serve to indicate the potential size of the replacement market, and projections of future energy use may indicate the size of the potential market for new coal-fired combustors in the industrial sector. In addition, examination of recent trends in the fuel mix in certain industries (such as cement manufacture) where coal has been proven to be able to effectively replace gas and oil, can help to determine to what degree these industries have already switched to coal and to what degree potential for switching still exists.

The following questions guided the country ratings for Factor 5:

- What was the total use of energy (including electricity, but excluding metallurgical coal use in the iron and steel industry*), in the industrial sector over the last decade?
- What is the projected growth of energy in the industrial sector between 1985 and 2000?
- What percent of total industrial energy use was supplied by coal (excluding metallurgical coal) over the last decade?
- What percent of total industrial energy use is projected to be supplied by coal (excluding metallurgical coal) in 2000?
- What is the current (1985) ratio of oil consumption to natural gas consumption in the industrial sector?
- What are the major industries in the country?
- What percent of total annual energy was supplied by coal over the last decade in the following industry groups: cement (non-metallic minerals); chemicals and petrochemicals; transport equipment and machinery; food, beverage and tobacco; and other industry (excluding iron and steel). What was the total annual energy use in those industry groups over the last decade?

The answers to these questions can be found in Appendix 5.

As in the case of Factor 4, the ratings for Factor 5 were most strongly influenced by the growth projected for total energy demand. Current demand, which indicates the potential retrofit market, and current/historical coal share were also strongly weighted. Projected coal share influenced the ratings less than the projected total energy demand and the historical coal share. The trend in the coal share in the specific industry groups also slightly influenced the ratings; an historical decrease in the coal share, particularly in the cement industry, generally tended to lower the rating. However, since such a decrease can also be interpreted to mean that a potential exists to reconvert the industry to coal, this element was not given a strong weight in the rating process.

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* Fuel use in the iron and steel industry is excluded because most of the "fuel" use is metallurgical coal that is used as input to coking ovens to produce coke, a feedstock in steel production.

2.3 FACTORS RELATED TO ADVANCED COAL TECHNOLOGY (ACT) TRADE

Factor 6 deals with the general quality of trade relations between the U.S. and the OECD countries. Factor 7 deals more specifically with the prospects of exporting ACT to OECD countries, given the levels of research and development on ACT and of ACT production within each OECD country.

2.3.1 Factor 6: Trade Relations

A climate favorable to trade with the U.S. could strongly influence the success of U.S. coal-technology export initiatives. The trade issue encompasses financial, security, and economic issues. One measure of the strength of trade relations between the U.S. and a foreign nation is the percentage of total imports that come from the United States. A related element is the trade imbalance between the United States and the nation (i.e., the difference between the value of exports to the U.S. from the country and the value of the U.S. imports into the country). An existing trade imbalance in the other country's favor (i.e., a trade surplus) is generally seen as an incentive to import more U.S. goods as a means of moving toward trade equilibrium, although a trade deficit does indicate a precedent for U.S. imports by the nation. An overall current account deficit in the country suggests that the country will have a tendency to try to replace expensive imports with goods made domestically or to look to other import sources. In addition to issues related directly to trade imbalances, certain trade restrictions or policies of some nations could thwart initiatives for U.S. exports, even if other conditions in the country favor increased coal use. Aside from specific trade issues, other factors which imply leverage to the U.S. for enhancing trade with a country are a strong mutual defense agreement/commitment (e.g., NATO involvement or U.S. military presence) and, in a few instances, support of the country through the U.S. AID program. The level of U.S. investment in the country can also be viewed as a minor indicator of U.S. trade relations with that country.

The following questions guided the country ratings for Factor 6:

- o What is the U.S. share of the country's imports? What is the U.S. share of exports from the country?
- o What is the trade imbalance between the country and the U.S.

(i.e., the difference between the value, in U.S. dollars, of U.S. exports from the country and the value, in U.S. dollars, of U.S. imports to the country)?

- Has any recent change in the trade imbalance been strongly influenced by depreciation/inflation of the U.S. dollar?
- Is the U.S. restricted in any way (e.g., via product quality requirements) from trade with the country?
- Do any cooperative agreements exist between the country and the U.S. which encourage trade, especially trade related to advanced technology, energy technology, or energy products?
- Does the country currently import energy products (e.g., coal) or energy technology (e.g., boilers) from the U.S.?
- How much investment by the U.S. private sector is currently occurring in the country?

The answers to these questions can be found in Appendix 6.

The current percentage of imports and the trade imbalance between the U.S. and the nation were viewed as the most important pieces of information in the rating process for Factor 6. A trade deficit combined with a current account deficit tended to move a country toward a lower rating. A strong U.S. presence in the country for reasons of security/defense or development assistance influenced the analysis in favor of a higher rating. Another element that tended to increase the ratings fairly strongly was current imports of U.S. coal or boilers. Cooperative agreements between the government of the country and the U.S. Department of Energy regarding fossil-energy R&D projects were factored into the rating in a few cases.

2.3.2 Factor 7: Lack of Domestic Competition to U.S. Technology

Countries that have no domestic ACT industry would be much more likely to import U.S. technology than those that have a strong ACT industry. The level of government and private spending on ACT research and development (R&D) can also indicate whether the country has developed or is interested in developing such an industry. Of particular interest to this analysis is R&D related to small combustors (particularly atmospheric fluidized bed combustors), coal/water mixtures, cogeneration, and district heating.

The following questions guided the country ratings for Factor 7:

- Does the country have its own energy-technology industry with which U.S. technology producers would have to compete?

- What percent of the government R&D budget is directed toward development of advanced coal technologies for the res/comm/industrial sector? How much private R&D?

- Toward which technologies is most of the R&D directed?

The answers to these questions can be found in Appendix 7. The questions were weighted about equally in the process of rating the countries.

2.4 FACTOR 8: ENVIRONMENTAL PRESSURE FOR ACT

One reason that oil and gas are often favored over coal, especially in the residential, commercial and industrial sectors, relates to environmental concerns -- particularly to emissions of SO_2, NO_x, and particulate matter from coal combustion and to the disposal of solid waste products. Advanced coal technology, however, may offer a way to use local or imported coal in countries with existing stringent regulations or growing environmental awareness.

The following questions guided the country ratings for Factor 8:

- What environmental regulations exist for the combustion of coal or coal products in small boilers and in major urban areas?

- Is the country committed to a reduction in acid-rain precursor emissions as part of the "30% protocol" agreement or similar domestic policy?

- If the country currently has no emission regulations affecting small, coal-fired boilers, are any such regulations being considered for those sources due to poor air quality or increased environmental awareness?

- Would advanced coal technologies be able to comply with existing or planned emission regulations?

- Are domestic coal types or currently imported coal considered adequate to comply with environmental policies without further clean up or use of advanced coal combustion technology?

- What regulations or policies exist for disposal of solid wastes from combustion?

The answers to these questions can be found in Appendix 8. The questions related to air issues were generally weighted more heavily than the solid waste issue.

3 RESULTS

The ratings by factor for the fifteen OECD countries examined in this analysis are presented in a matrix format in Fig. 1. A general explanation of the ratings can be found in Sec. 3.1. This is followed by country profiles for all fifteen countries, grouped according to their prospects for use of U.S.-developed ACT (Sec. 3.2). The recommended choices for three countries for further study are found in Sec. 3.3.

3.1 COUNTRY/FACTOR RATINGS

Factors related to the general energy situation. Only five of the fifteen countries (Belgium, France, Japan, the Netherlands and Sweden) are rated "low" or "low-medium" for Factor 1 (Energy Plan/Situation). In the other countries, coal is being promoted in the energy plan and/or coal is either readily available through indigenous resources or is being imported at fairly significant or increasing levels. High ratings for Factor 1 are not always linked with high dependency on oil/gas imports (Factor 2). Australia, Canada, Finland, Germany, and the United Kingdom are rated "low" or "low-medium" for Factor 2, but were nevertheless favorably disposed to coal, as indicated by their ratings for Factor 1. Additionally, in several countries (Belgium, France, and Japan) oil imports are fairly high, but ratings for Factor 1 are "low-medium" because energy resources other than coal (primarily nuclear and renewables) are being promoted more heavily than or just as heavily as coal. Many of the countries that were rated "high" or "medium-high" for Factor 1 also had considerable experience with coal and coal handling and were therefore rated "high" or "medium-high" for Factor 3 (this is true for Australia, Canada, Germany, Spain, and the United Kingdom). However, some countries favor coal use without having had much experience with it and/or without having an adequate transportation network for its transfer to demand centers (Finland, Greece, Italy, Portugal, and Turkey); this could present some constraints to increased coal use in those countries. Considering Factors 1, 2, and 3 together, two-thirds of the countries appear to have general energy conditions that favor increased coal use, as follows: Australia; Belgium; Canada; Germany; Greece; Italy; Japan; Spain; Turkey; and the United Kingdom.

Factors related to energy demand. Residential/commercial energy demand (Factor 4) and industrial energy demand (Factor 5) were rated fairly high in countries that have either high projected population and industrial growth or high current energy demand (indicating a potentially large retrofit market). Considering Factors 4 and 5 together, the following ten countries are rated fairly high for new/retrofit energy demand:

	General Energy Situation Factors			Energy Demand Factors		Trade Factors		Environmental Factors
	1	2	3	4	5	6	7	8
Country	Energy Plan/ Situation	Oil/Gas Import Dependency	Coal Experience	Residential/ Commercial Energy	Industrial Energy	Trade Incentives	Lack of Domestic Competition	Environmental Pressure for Advanced Technology
Australia	High	Low	High	Med-High	Med-High	Med-High	Low-Med	Low
Belgium	Low-Med	Med-High	Med-High	Low-Med	Low	Low-Med	Low-Med	Low-Med
Canada	Med-High	Low	Med-High	Med-High	Med-High	High	Med-High	Med-High
Finland	Med-High	Low-Med	Low-Med	Low-Med	Low	Low	Low-Med	Med-High
France	Low-Med	Med-High	Med-High	Med-High	Med-High	Low-Med	Med-High	Med-High
Germany	Med-High	Low-Med	High	Med-High	Med-High	Med-High	Low	High
Greece	High	High	Low-Med	Low-Med	Med-High	Low-Med	High	Med-High
Italy	Med-High	High	Low-Med	Med-High	Med-High	Med-High	High	High
Japan	Low-Med	High	Med-High	Med-High	High	Med-High	Low-Med	High
Netherlands	Low-Med	Low-Med	Med-High	Low	Low	Med-High	Low-Med	High
Portugal	High	Med-High	Low	Low	Low-Med	Low-Med	High	Low-Med
Spain	High	High	Med-High	Med-High	Med-High	Med-High	Med-High	Med High
Sweden	Low-Med	Low-Med	Low	Low-Med	Low	Low-Med	Low-Med	High
Turkey	Med-High	Med-High	Low-Med	High	High	Med-High	High	Low-Med
U. K.	Med-High	Low	High	Low-Med	Med-High	Med-High	Low-Med	Med-High

FIGURE 1. Country Ratings, by Factor.

Australia; Canada; France; Germany; Greece*; Italy; Japan; Spain; Turkey, and the United Kingdom.

Trade Factors. Ratings for Factor 6 (Trade Relations) are highest for Australia, Canada, Germany, Italy, Japan, the Netherlands, Spain, Turkey, and the United Kingdom. These countries currently import a large portion of their goods from the United States or have other favorable trade conditions with the United States. However, the presence of an ACT industry in a country could thwart U.S. efforts to export ACT to that country, even if trade relations are strong. Domestic competition was seen as a fairly strong impediment (indicating a low or low-medium rating for Factor 7) in the following countries: Australia; Belgium; Finland; Germany; Japan; the Netherlands; and Sweden, and the United Kingdom. Overall, the following countries are thought to present fairly good ACT trade possibilities: Canada; France; Greece; Italy; Portugal; Spain; and Turkey.

Environmental Pressure for ACT: Demand for ACT will be highest in those countries that have fairly stringent air pollution control requirements which can not generally be met by uncontrolled, conventional coal-combustion technology. Those countries in which such environmental pressure exists, as indicated by high or medium-high ratings for Factor 8, include the following: Canada; Finland; France; Germany; Greece; Italy; Japan; the Netherlands; Spain; Sweden; and the United Kingdom.

3.2 COUNTRY PROFILES

Based on the country/factor ratings in the four areas described above in Sec. 3.1, the countries are grouped into three categories, as follows:

1. Countries with good potential markets for U.S. advanced small-combustor technology: Italy; Spain; Turkey; Greece; and Canada.

2. Countries with some potential, but for which some serious impediments exist: Australia; France; Germany; Japan; Portugal; and the United Kingdom.

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* Note that although Greece is rated low-medium on residential/commercial energy demand because of the low absolute amount of energy consumed and the low current coal share, the growth rate of residential/commercial energy use in Greece is projected to be almost 3% per year. Therefore, the market in Greece would be a market primarily for new, rather than retrofit, combustors, so the overall prospects for new combustors are rated to be fairly good in Greece.

3. Countries for which the potential appears small, due to the presence of many impediments: Belgium; Finland; the Netherlands; and Sweden.

The countries grouped into category 1 are those for which a fairly high overall rating was given in each of the four broad factor areas. Note that although Turkey was rated low-medium for Factor 8 (Environmental Pressure), it was rated generally high in the other three factor areas, and the fact that environmental awareness is just emerging in Turkey was not seen as an overriding constraint to use of ACT there. A profile of each of the fifteen countries is included in the three sections below.

3.2.1 Countries with Good Potential Markets

Conditions favoring and discouraging increased use of U.S.-developed ACT for the residential, commercial and light-industrial markets in the five most promising countries are described below.

3.2.1.1 Italy

Italy is highly dependent on oil imports, significant amounts of which are from OPEC and the centrally planned economies, and relies on natural gas from the U.S.S.R. for 22 percent of its gas requirements. (Italy received a "high" rating for Factor 2 -- Oil/Gas Import Dependency.) Until recently, nuclear power production was seen as a primary means of reducing this dependency; since the Chernobyl accident, however, the nuclear program is being reconsidered. Increased use of coal in power stations is seen as another way of improving Italy's energy situation; most of the increase in coal consumption called for in Italy's National Energy Plan is expected to occur in power plants.

Although Italian coal production is low relative to the other countries considered, the last decade has seen a 60 percent increase in production; moreover, Italy now has the second highest level of coal imports of all the countries considered. A large portion of this imported coal comes from South Africa, although U.S. imports accounted for about 40% of all steam coal imports to Italy in 1985. It is possible that South African imports will decline in the future, and that imports will rise from sources that are less politically "sensitive", such as the United States. The attitude toward coal expressed in the energy plan and the recent trend in coal imports are the primary factors contributing to the "medium-high" rating for Factor 1.

Italy's experience with coal is fairly recent, leading to a "low-medium" rating for Factor 3. In 1985, coal supplied only eleven percent of the country's total primary energy requirement, up from six percent in 1973. Electricity production by coal-fired power plants increased from about 5 TWh to 30 TWh over the same period. A potential constraint to increased use of coal is related to the coal-transportation infrastructure; rail networks to transport coal to Italy's interior appear somewhat inadequate at this time.

Considering Factors 1, 2, and 3 together, the current climate in Italy is thought to be quite favorable to increased coal use. The coal transportation problem is not seen as an overriding constraint; it would not strongly impact the numerous potential coal-combustion sites along Italy's protracted coastline.

Both energy demand factors were rated "medium-high" for Italy. Current total energy use in both the residential/commercial and industrial sectors is fairly high, indicating a substantial retrofit market. Residential/ commercial use has been increasing at one percent per year since 1973, and this trend is projected to continue through 2000; projected growth in industrial sector use is somewhat lower. Although coal's share of residential/commercial energy use was less than one percent in 1985, this share is expected to increase by 2000. Coal supplies a greater proportion of energy use in the industrial sector than in the residential/commercial sector; it is expected to supply 12% of total industrial energy use by 2000. Although coal's share of energy use in the cement and chemicals industries declined over the period 1970-85, it has been growing in other industrial categories. Italian industry uses twice as much oil as gas, a factor that might encourage conversion to coal in a country, such as Italy, that imports so much of its oil. Overall, the prospects for new combustors -- in both retrofit situations and new facilities -- are quite promising in Italy.

Italy appears to offer good prospects for trade with the United States. In 1985, 11% of total imports to Italy came from the United States; coal was one of the principal U.S. imports. Italy currently has a fossil fuels R&D cooperative agreement with the U.S. The country's own investment in coal R&D is quite low and little private coal R&D or advanced coal technology manufacturing is being carried out, implying very little competition for U.S. suppliers of ACT. Italy's interest in coal is very recent, and the government is planning some ACT demonstrations. These factors suggest an excellent opportunity for introduction of U.S.-manufactured ACT.

Environmental pressure for advanced coal technologies is also high. Local air pollution is a primary concern. There are no federal emission regulations for boilers with capacity below 100 MWt, but coal is limited to 1% sulfur-in-fuel. Although environmental emphasis is on large plants, for which FGD systems are being promoted, a potential role exists for ACT at smaller units to help achieve the goals of an overall 30% reduction in

SO_2 emissions and ameliorate waste disposal problems.

Of all the countries considered, Italy appears to be the most promising export market for U.S.-developed ACT for small combustors, based on the analysis of the eight factors.

3.2.1.2 Spain

Spain is very dependent on imported energy; in 1985, over 50% of Spain's total primary energy requirement was met by imported oil, and a large portion of these imports were from OPEC countries. (Hence, Spain was rated "high" for Factor 2 -- Oil/Gas Import Dependency.) The National Energy Plan of Spain calls strongly for reduced energy import dependence. A special effort is being undertaken to substitute coal for oil products in industry and urban areas through initiatives such as creation of regional coal stockpiles and investment subsidies, though response to this plan has been fairly modest, given currently low oil and gas prices. Spain has indigenous coal resources and a moderate but increasing level of coal production. However, due to difficult mining conditions and hence high production costs, in the past few years average domestic coal prices have been higher than prices of imported coal. (Imported-coal prices have been low due to an unusually depressed international coal market.) Therefore, imports of coal to Spain, a large portion of which are from South Africa, have been on the rise. These conditions in Spain led to a rating of "high" for Factor 1 (Energy Plan/Situation). Spain is also rated "medium-high" for coal experience (Factor 3), since it has moderately high and increasing use of coal in power production, decreasing use of nuclear power, fairly high port capacity, and an adequate coal-transport (railway) network. Overall, the general energy situation, as measured by the criteria addressed in Factors 1, 2, and 3, appears to strongly favor increased coal use in Spain.

Spain was rated "medium-high" for both of the energy demand factors (Factors 4 and 5). Although current energy demand in the residential/commercial sector is moderate (at 16 Mtce), demand has been growing at 3.6%/yr during the 1973-1985 time period, and is projected to continue to grow -- at a steady 1%/yr -- between 1985 and 2000. The coal share of total energy demand in the residential/commercial sector is currently a modest 3%, but has shown an increase since 1973 and is projected to grow to 8% by 2000. The growth in energy demand in the industrial sector is projected to be quite high between 1985 and 2000 in Spain (an increase of 16 Mtce in that time period), and the coal share is projected to increase from 6% in 1985 to 12% in 2000. In both the residential/commercial and industrial sectors, oil use is much higher than natural gas use; therefore, the incentive to increase coal use in order to reduce oil imports is quite strong in these sectors in Spain.

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Trade relations (Factor 6) between the United States and Spain are rated "medium-high". Spain currently imports coal from the United States and is engaged in a fossil-energy research agreement with the U.S. Department of Energy. Additionally, the Spanish government is committed to developing high technology in Spain and is promoting application of new technologies to existing Spanish industries. The Spanish government and private investors are funding some ACT R&D in Spain and some manufacturing of coal-technology is being undertaken; however, the level of R&D spending per GDP is quite low in Spain compared to other OECD countries. Spain is therefore rated "medium-high" for Factor 7 (Lack of Domestic Competition). In general, trade conditions for the export of U.S. ACT to Spain are considered generally favorable.

Environmental pressure for ACT in Spain is also rated "medium-high". Spain's policy is to achieve emission reductions in the longer term by developing and utilizing new technologies that can burn indigenous coals cleanly and efficiently. Fluidized-bed combustion is of emerging interest in Spain.

Overall, there do not seem to be impediments to coal use or constraints to U.S. export initiatives in Spain. On the contrary, most conditions seem to favor Spain as a market for U.S.-developed ACT for small combustors.

3.2.1.3 Turkey

Turkey's energy reserves include large stores of fairly poor-quality lignite and some hard coal. Although lignite production increased substantially over the last decade (from 3 to 12 Mtce between 1973 and 1986), coal users in Turkey have turned increasingly to imported coal. Coal imports, primarily from the United States, rose from 10,000 tons in 1973 to an estimated 3 million tons in 1986. However, almost 40% of the total primary energy requirement in Turkey is currently supplied by imported oil, and a large portion of that comes from OPEC and the U.S.S.R.. Oil imports have not declined over the last decade. Hence, government energy policy objectives in Turkey include increased domestic energy production. Although the government is also encouraging renewable sources (primarily hydroelectric), interest is very high for clean combustion of lignite and increased use of coal (both domestic and imported). Furthermore, the country currently uses a large amount of wood and animal dung for fuel in rural areas, and development of replacements for these fuels might be encouraged for environmental reasons.

Increased coal use in Turkey will be somewhat constrained by low port capacity and lack of an adequate transportation network (inland transport of coal is currently accomplished primarily by truck). Additionally, coal will soon have to compete with natural gas to be supplied by a new pipeline from the Soviet Union. Nevertheless, the general energy situation in Turkey quite strongly favors increased coal use, due to the current high coal share of total primary energy requirements (almost 30% in 1985), the indigenous coal and lignite reserves, and the increase in its level of imports in recent years.

Turkey is an industrializing country with a rapidly growing population, and thus has high prospects for increasing energy demand. Between 1973 and 1985, residential, commercial, and industrial energy use combined rose by almost 60%. This increase is projected to continue at an even more rapid rate in the future; between 1985 and 2000, residential/commercial energy use is projected to double and industrial energy use to increase by almost a factor of three. The coal share of residential/commercial energy use, already quite high at 13%, is projected to double between 1985 and 2000. Annual coal use in industry is projected to increase by almost 5 Mtce over the next 15 years. Although no district-heating or combined-heat-and-power capacity is currently installed, the government is currently carrying out R&D on these systems. Overall, the energy demand situation in Turkey looks encouraging for increased use of ACT.

The environment for trade with Turkey, especially trade related to ACT, also appears to be quite good. A fairly substantial portion (11%) of imports to Turkey come from the United States, and coal is the second largest U.S. import. The levels of ACT R&D and manufacturing are minimal in Turkey, yet a strong demand exists for ACT for clean lignite combustion.

Environmental awareness in Turkey is just emerging. Air pollution regulations were passed in 1986, but do not appear to be very stringent. Turkey is looking for ways to burn lignite more cleanly, especially in fairly polluted areas, such as Ankara. However, despite some concern over pollution levels, the environmental pressure for advanced technology is considered relatively small at present, and therefore Turkey was rated "low-medium" for Factor 8. The lack of stringent air pollution control requirements is not seen as an overriding constraint to ACT use in Turkey since, in addition to reducing emissions, ACT also generally provides a means for more efficient utilization of coal and would therefore be more desirable than conventional systems. As such, there appear to be no major constraints to, and several strong incentives for, exportation of U.S.-developed ACT for small combustors to Turkey.

3.2.1.4 Greece

Having few indigenous energy resources, Greece is highly dependent on foreign oil and gas. (The rating for Greece for Factor 2 -- Oil/Gas Import Dependency -- was "high".) The country has made great strides toward reducing this dependency over the last decade or so; oil imports supplied 58 percent of Greece's total primary energy requirements in 1985, down from 91 percent in 1973. Government policy favors the use of renewables, imported coal, and increased use of domestic lignite to reduce oil import dependency. Coal imports have doubled since 1973 and coal production has tripled over the last decade; coal's share of the total primary energy requirement increased from 17 percent in 1973 to 33 percent in 1985. Thus, Greece was rated "high" for Factor 1 (Energy Plan/Situation). Greece's experience with coal, however, is fairly recent. Improvements in the country's infrastructure for reception and transportation of coal will be needed if coal use is to continue to increase. (This constraint led to a "low-medium" rating for Factor 3 -- Coal Experience). However, because the pressure for increased coal use appears to be quite high, as evidenced by the large increases in coal imports, coal production, and the coal share of energy requirements, the general energy situation in Greece must be viewed as favoring coal use.

Though market prospects for coal combustors appear fairly limited in the residential/commercial sector, the industrial sector offers somewhat better potential for new combustors. Total energy use in both sectors is low, but is increasing and is expected to continue this increasing trend through 2000. Though coal's share of total residential/commercial energy use is low, its share of industrial energy use is 28 percent, up from eight percent in 1973. The coal share of energy used is increasing in three major industry categories: cement (70% in 1985), chemicals, and transport equipment/machinery. Coal conversion in the industrial and residential/commercial sectors might be heavily promoted, as current non-coal energy use in these sectors is mainly oil. Greece received a rating of "medium-high" for current and projected energy use.

Greece offers a somewhat mixed picture in terms of trade prospects. Its imports from the United States are low (only 7 percent of total imports in 1985), and Greece is a recent member of the European Economic Community, implying that it will turn increasingly to European trade partners. These considerations led to a "low-medium" rating for Factor 6 (Trade Relations). However, Greece currently imports over 50% of its steam coal from the United States. Moreover, Greek experience with advanced coal technology is limited: government budgets for coal R&D are very low and little private coal R&D or advanced coal technology manufacturing are being carried out. This lack of experience implies a good opportunity for American manufacturers of ACTs.

Though Greece has no existing federal environmental regulations, the need to reduce SO_2 emissions, a strong environmental awareness related to a desire to preserve the country's ancient monuments, and recent urban planning measures lead to a "medium-high" rating for Factor 8 and imply a potentially large role for ACT.

Considering all four factor areas, Greece appears to have fairly high prospects as a potential export market for U.S.-developed ACT for small-combustor applications.

3.2.1.4 Canada

Canada has abundant reserves of oil, gas, and coal, and is a net exporter of all three. Canada also produces a large percentage of its electricity via hydropower, and a significant portion (15% in 1985) of its industrial energy demand is supplied by wood. Because its energy resources are so diverse, only 11 percent of Canada's total primary energy requirement was met by coal in 1985. The government energy plan contains no explicit policies encouraging greater coal use; however, some provincial governments have shown a strong interest in coal technologies. Nevertheless, Canada received a "medium-high" rating for both Factor 1 (Energy Plan/Situation) and Factor 3 (Coal Experience) for the following reasons: coal is readily available; coal production has increased in recent years; coal is currently being used quite widely in power plants; and the coal-transportation network is adequate and expanding. However, the incentives for increased coal use in Canada are not as strong as they are in countries such as Italy, Spain, Turkey, and Greece, which are currently highly dependent on imported oil.

Both current and projected energy demand in the residential/commercial and industrial sectors are quite high in Canada, implying that the potential markets for both retrofit and new combustors will be good. An especially large increase in industrial energy demand (34 Mtce) is projected for the period between 1985 and 2000. Coal's share of current energy demand is small, although it is projected to increase slightly in the industrial sector. Canada is highly urbanized and high population growth is expected over the next fifteen years.

Canada offers good prospects as a trading partner. Seventy-nine percent of its imports in 1985 were from the United States. Canada and the U.S. are currently engaged in trade negotiations with the ultimate objective of reducing or eliminating tariffs and other barriers to trade between the two countries. Hence, Canada received a "high" rating for Factor 6 (Trade Relations). Although the Canadian government appears to be reducing its support of coal R&D, some private coal R&D and some advanced coal technology manufacturing are taking place. A strong demand for advanced coal technology exists in Canada, along with an interest in U.S. suppliers of such technology. Canada received a rating of "medium-high" for Factor 7 (Lack of Domestic Competition).

Environmental pressure for advanced coal technology is also fairly high in Canada. Provincial regulations call for a 50 percent reduction in SO_2 emissions by 1994, though it should be noted that some of this reduction is achievable through increased use of hydro and nuclear power and use of low-sulfur coals.

Because of the high projected energy growth, the favorable trade conditions, the high level of environmental pressure, the high availability of coal, and the considerable experience with coal, opportunities for export of U.S.-manufactured ACT for small combustor applications to Canada appear quite favorable.

3.2.2 Countries with Good Markets but Some Impediments

Six countries fell into this category. Factors favoring and discouraging increased exports of U.S. ACT technology to these countries are described below.

3.2.2.1 Australia

The Australian government is committed to using its abundant indigenous energy resources, especially coal and natural gas. Over the last decade, the country has greatly reduced its oil imports, which were never very high. In 1985, imported oil supplied less than one percent of Australia's total primary energy requirement.

A major coal producer, Australia currently relies on indigenous coal for 40 percent of its energy requirements and is one of the few OECD countries studied which has no current or planned nuclear power generation. Although Australia received a "low" rating for oil and gas import dependency (Factor 2), its rating for Factor 1 (Energy Plan/Situation) and Factor 3 (Coal Experience) are both "high", owing to its high level of coal production, its extensive experience with coal, and the government's commitment to increased coal use.

Australia was rated "medium-high" for both of the energy-demand factors (Factors 4 and 5). Although total energy use in the residential/commercial and industrial sectors is moderately low, implying fairly small potential retrofit markets, energy use in both of these sectors has been increasing over the last decade, and a healthy increase between now and 2000 is forecast. Coal currently supplies a small portion of total residential/commercial demand, but a fairly substantial (13%) share of the industrial demand. It should be noted that, in some respects, the residential/commercial sector in Australia is in a favorable situation for conversion to coal: the country is highly urbanized, simplifying distribution of fuel supplies, and the residential/commercial sector uses almost four times as much oil as gas, indicating that the incentive to switch to coal might be fairly high.

In 1985, 28% of Australia's imports were from the United

States, and these imports did include U.S. boilers. However, since the Australian government is committing substantial resources to coal R&D and some ACT manufacturing is taking place in the country, U.S. manufacturers are likely to meet with considerable competition.

The country also offers no real prospects for U.S.-developed advanced coal technology from an environmental perspective. Australia has no acid rain problems, and existing regulations allow uncontrolled burning of low-sulfur coals. There are no NO_x regulations for units with capacity of less than 150 MM Btu/hour.

Therefore, although increased coal use is favored in Australia and energy demand growth is projected to be fairly high, competition from domestic manufacturers and lack of strong pressure to use ACT for environmental reasons are seen as fairly strong impediments to the export of U.S. ACT to Australia.

3.2.2.2 France

France is fairly dependent on imported energy and imports large amounts of oil and natural gas from OPEC and the centrally-planned economies. However, France has made a strong commitment to nuclear power for its late twentieth-century energy needs and in 1985 was the largest producer of nuclear electricity of the countries studied. Although coal production has decreased by 40% over the last decade, there is some political pressure in France to restore production to the higher levels on the 1950's and 1960's. Moreover, imports have increased by 30% over the last decade. Coal's share of the total primary energy requirement has decreased over the same period, though electricity production from coal is fairly high in France. Although much of the general energy situation in France appears to favor increased coal use, the preponderance of nuclear power in the country's energy picture tends to limit the potential for such increased use.

Nevertheless, high total current energy demand and fairly high coal share of total energy demand led to "medium-high" ratings for both of the energy demand factors (Factors 4 and 5). Although total use of energy in the residential/commercial sector in 2000 is projected to be about the same as in 1985, coal use is projected to increase in that sector by about 6 Mtce. The coal share in industry is also projected to increase -- from 8% in 1985 to 12% in 2000. Total current energy use in both these sectors is fairly high, indicating a good potential retrofit market. Both sectors use about twice as much oil as gas, strengthening incentives to switch to coal.

Some coal technology has historically been manufactured in France; however, the French have little experience with advanced coal technology. Technology for small-combustor applications would be of great interest to the French. However, only seven percent of 1985 imports to France were from the United States, indicating that the French usually prefer other trading partners over the United States.

Environmental pressure for advanced coal technology is fairly high in France. The French are aiming for a 65% reduction in SO_2 emissions by 1995 and a reduction of 20 to 30 percent in NO_x emissions by 2000. These goals are expected to be achieved through increased use of nuclear power, fuel substitution, and sulfur-in-fuel limits; however, advanced coal technology could possibly compete with low-sulfur coal in protected urban areas.

Several factors -- environmental pressure, projected increases in energy demand, and increased coal shares in the residential/commercial and industrial sectors -- indicate that some potential for increased use of ACT exists in France. However, the heavy dependence on nuclear energy and some negative aspects of the trade relationship between the U.S. and France tend to limit that potential.

3.2.2.3 The Federal Republic of Germany

The Federal Republic of Germany (FRG) is the largest coal producer and the highest producer of coal-generated electricity of all the countries considered. The government's energy policy objectives include increasing the role of coal in the country's energy mix. The German government subsidizes the domestic hard coal industry. Coal supplied about 30 percent of the country's total primary energy requirement in 1985. Although most of Germany's oil imports come from other OECD countries, making the country relatively invulnerable to supply interruptions, the FRG's historical use of coal, its adequate transportation network, and its favorable attitudes toward coal use contribute to generally high ratings for Factors 1 (Energy Plan/Situation) and 3 (Coal Experience).

Both the residential/commercial and industrial sectors in the FRG offer good potential retrofit markets. Though energy use in the residential/commercial sector is projected to decline, total energy use in this sector is currently the highest of all the countries considered. Coal's share of this energy is low, but the country does have some installed coal-fired district heat and cogeneration capacity, and the government is investing in coal-fired cogeneration systems. Coal supplies about ten percent of industrial energy use, but this share is expected to decrease by 2000. Both the residential/commercial and industrial sectors use a considerable amount of oil (compared to gas); therefore conversion to coal may be quite desirable. Because of the high potential retrofit market in these two sectors and the government's promotion of coal-fired cogeneration systems, the FRG is rated "medium-high" for both of the energy demand factors (Factors 4 and 5).

Environmental pressure for advanced coal technology is high in Germany. Detailed emission regulations for large and small plants, both new and existing, are already in place. Though low-sulfur coal is adequate for small installations, considerable demand exists for fluidized bed combustors or other advanced coal technologies. The government is offering tax relief for installers of advanced coal technologies.

In spite of its high ratings on the above factors, the FRG does not appear to offer very good prospects for trade with the U.S. in advanced coal technology. Although several factors favor trade with Germany, including a trade surplus in Germany's favor and a strong U.S. political alliance with that nation, the German government and private industry in the F.R.G. are heavily involved in coal R&D and advanced coal technology products are manufactured in the country. U.S. suppliers of ACTs would likely meet strong competition from German suppliers. As a result of these factors, the FRG is rated fairly low on trade issues. A low rating on this factor tends to override some of the other positive factors in Germany's favor and to bring its overall rating down from an otherwise high level.

3.2.2.4 Japan

Japan has few indigenous energy resources so must rely heavily on imports. Fifty-seven percent of the country's total primary energy requirement in 1985 was met by imported oil, mostly from OPEC countries. Japan is seeking a balanced mix of energy sources, including nuclear, coal, hydropower, and renewables, to help reduce this reliance on imports. Japan produces only a moderate amount of coal, and this production has been decreasing over the last decade; however, in 1985 Japan was the largest importer of coal of all the countries considered. Although Japan's industrial coal use is primarily in the iron and steel industry, its coal-generated electricity production is the third highest of all the countries considered (about 100 TWh in 1985) and has shown large increases since 1973. However, the country is moving toward increased nuclear power production, and nuclear electricity has increased at a much faster rate than coal over the period 1973-85 (from less than 10 TWh in 1973 to over 159 TWh in 1985). Therefore, although increased coal use should be seen as a viable option in Japan, the country is not committed to coal utilization to the exclusion of other energy sources.

Japan has the highest total industrial energy use and the second highest residential/commercial energy use of all the countries considered. Energy use in both these sectors is expected to increase through 2000. Coal's share of total residential/commercial use is less than one percent and has been decreasing, while the coal share of industrial energy use is increasing and is expected to be about 16 percent in 2000. The cement industry already uses coal for 62 percent of its energy needs. Although this industry may be close to its capacity for coal use, other industries seem to have potential for conversion to coal. Japan is fairly urbanized and projects moderately high growth in population by 2000; these factors, combined with the high total energy use and the fact that four times more oil than gas is used in the residential/commercial sector, suggest a good potential market for both retrofit and new combustors. Therefore, Japan is rated "medium-high" for Factor 4 (Residential/Commercial Energy Demand) and "high" for Factor 5 (Industrial Energy Demand).

Environmental pressure for advanced coal technology is high in Japan. A strong SO_2 and NO_x control program is in place at both federal and local levels. Flue gas desulfurization and $deNO_x$ technologies are used on large plants, mostly with waste minimization techniques.

Japan looks less promising when viewed from a trade perspective. Although the country has a high level of U.S. imports (23% in 1985), including a small amount of coal, and has bilateral R&D agreements with the U.S., Japan is a leader in domestic coal R&D and commercial activity. The Japanese government's budget for coal R&D is the highest of all the countries considered, a high level of private coal R&D is being carried out, and ACTs are widely manufactured in the country. The very stiff competition the U.S. would meet from domestic suppliers is seen as a very strong impediment to exportation of U.S.-developed ACT to Japan.

3.2.2.5 Portugal

Portugal has a history of heavy dependence on energy imports: in 1985, 67 percent of the country's total primary energy requirements were met by oil imports and this level of imports has changed little since 1973. Portugal's situation as an oil importer is fairly secure, however; most of the imports are from OECD countries (lowering an otherwise "high" rating for Factor 2 to a "medium-high").

Primary objectives of the national energy plan of Portugal include development of indigenous resources and diversification of energy supplies. The Portuguese government has stressed the importance of coal as a primary energy source and has established a program of grants to cover 15-30% of the cost of projects for energy conservation, oil substitution, and/or stimulation of domestic energy production and use. Coal production is currently low, as are imports, but imports have increased greatly since 1973. Most coal imports come from the United States. Thus, Portugal's rating for Factor 1 (Energy Plan/Situation) is "high".

Portugal has very little experience with coal; coal's share of TPER was only six percent in 1985 and, as of 1983, a coal transportation infrastructure was not in place. Portugal received a rating of "low" for Factor 3 (Coal Experience). Therefore, although several important factors favoring increased coal use in Portugal are present, some fairly important constraints tend to make prospects there appear less promising.

In 1985, Portugal had the lowest residential/commercial energy use of all the countries considered; though this energy use has been increasing and should continue to do so through 2000, it is expected to remain low relative to the other countries considered. No coal is used in the residential/ commercial sector, nor are there any plans for coal use. Industrial energy use is also fairly low, but is expected to almost double by 2000, with a projected coal share of 12 percent by that year. A potentially large coal conversion market exists in the cement industry, where the coal share is currently only 18 percent. Only oil is used in industry now, so coal conversion would be fairly desirable, in light of the country's desire to reduce oil imports. However, due to the relatively low absolute levels of energy use in the residential, commercial, and industrial sectors in Portugal, the energy demand factors (Factors 4 and 5) are rated "low" for residential/commercial and "low-medium" for industry.

Although the United States and Portugal do conduct some trade -- eight percent of Portuguese imports are from the United States and coal is their second largest U.S. import -- Portugal has recently joined the European Economic Community (EEC) and is likely to turn increasingly to other EEC trading partners. Portugal is therefore rated "low-medium" for Factor 6 (Trade Relations). However, little coal R&D or ACT manufacturing are being carried out in the country; assuming Portuguese interest in ACT, U.S. suppliers would probably meet with little competition from domestic suppliers. Therefore, both positive and negative trade influences affect exportation of ACT from the United States to Portugal.

Environmental pressure for advanced coal technology is fairly low. Although some sulfur-in-fuel restrictions exist, there are no emission limits in place that would require controls or advanced coal technology. At present, environmental awareness is not strong and few incentives for ACT appear to exist in Portugal.

Impediments to exportation of U.S.-developed ACT for small combustor applications in Portugal can be summarized as follows: lack of coal-transportation infrastructure; low energy demand; competition from EEC countries for trade; and lack of environmental regulations that could be met with ACT. On the positive side, Portugal is very anxious to increase its coal use as a means to reduce oil imports and domestic competition for ACT is minimal.

3.2.2.6 The United Kingdom

Over the last decade, coal has consistently supplied over 30% of the total primary energy requirement in the United Kingdom. Most of the coal used is mined in the country; however imported coal, primarily from Australia, has begun to supply some power plants. The United Kingdom is therefore rated "medium-high" for Factor 1 (Energy Plan/Situation). Although there has been a fairly substantial increase in nuclear generating capacity in the United Kingdom over the last decade, in 1985 only about 10% of the capacity was nuclear and most of the remainder was coal-fired. Inland transportation networks, primarily rail, appear to be adequate in the country. Therefore, the rating for the United Kingdom for Factor 3 (Coal Experience) is "high". The government relies primarily on market forces in implementing its energy policy, the main objective of which is to ensure adequate and secure energy supplies at the lowest, long-term cost. The United Kingdom is a net exporter of petroleum (leading to a "low" rating for Factor 2) and also produces natural gas. These fuels compete with coal in the residential, commercial, and industrial sectors. Therefore, although the country's prior experience with coal and the availability of coal from domestic sources generally favor increased coal use in the United Kingdom, competition from domestic oil and gas may negatively influence prospects for increased coal use.

The United Kingdom is mainly a retrofit market for new combustors. Total energy demand in the residential/commercial sector in 2000 is projected to be virtually the same as it was in 1985, and growth in the industrial sector is projected to be fairly low. Although the coal share in the residential/commercial sector is currently fairly high at 13%, it has been decreasing (from 25% in 1973), and is projected to continue to decrease (to 9% in 2000). Domestically-produced natural gas is the primarily fuel used in the residential/commercial sector, and prospects for its replacement with coal in retrofit situations are probably not good, unless gas prices increase dramatically. The United Kingdom was therefore rated "low-medium" for Factor 4 (Residential/Commercial Energy Demand). However, some research into coal-fired district heating has been undertaken, and success in that area of research may provide some impetus for reversing the trend in residential/commercial coal use.

In the industrial sector, the coal share of energy use declined in every industry between 1970 and 1985. However, the coal share of total industrial energy use is projected to increase from 9% to 15% between 1985 and 2000, implying that some industries may reconvert some of their capacity to coal. The United Kingdom therefore received a "medium-high" rating for Factor 5 (Industrial Energy Demand).

In general, the United Kingdom is a fairly strong trading partner with the United States. About 11% of the United Kingdom's imports come from the United States, and the United Kingdom is the fifth largest purchaser of U.S. goods. Hence, the United Kingdom was given a "medium-high" rating for Factor 6 (Trade Relations). However, because the United Kingdom has a fairly strong domestic coal-technology industry and a considerable level of private ACT R&D, it was rated "low-medium" for Factor 7 (Lack of Domestic Competition).

The environmental pressure for ACT in the United Kingdom was rated "medium-high". New air pollution regulations have been proposed for industrial boilers that would require 30-90% reduction of SO_2. Therefore, a role exists for ACTs that have removal efficiencies of that order of magnitude.

In summary, although the United Kingdom was rated fairly high on many of the important factors considered in this analysis, two impediments to increased use of U.S.-developed ACT exist -- domestic production of oil and gas that competes with coal, and the existence of a fairly strong domestic coal-technology industry.

3.2.3 Countries with Limited Markets

Four countries were found to have limited markets for U.S.-developed ACT technology. These countries are described below.

3.2.3.1 Belgium

Belgium is highly dependent on imported oil (hence, a "medium-high" rating for Factor 2); however, most oil imports come from OECD countries. The nation is moving toward lessening its oil dependence through measures to encourage rational use of energy and diversification of supply. Nuclear power capacity has been increasingly brought on line to meet electricity demands. Currently, electricity capacity is in oversupply, and this condition is expected to continue in the near-to-medium term.

Conversion to coal is also being encouraged in all economic sectors in the Belgian energy plan. Coal-generated electricity and imports of coal have increased over the last decade. Since Belgian coal is very expensive to exploit, the government subsidizes the difference between the production cost per ton and the world market price for imported coal; in addition, coal is taxed at a lower rate than other fuels. Although these factors indicate some positive pressure from the government of Belgium to promote increased coal use, Belgium is rated "low-medium" for Factor 1 (Energy Plan/Situation), because the large increase in nuclear power production and the oversupply of electric generating capacity will force coal to compete very strongly with electricity in the residential/commercial and light-industrial sectors.

Domestic coal production is currently fairly limited but was much higher in the past (during the 1950's and 1960's). Coal supplies over 20% of the primary energy requirement in Belgium, and the transportation infrastructure is good. Therefore, Belgium is rated "medium-high" for Factor 3 (Coal Experience). However, as discussed above, prospects for increased coal use are limited by the current oversupply of electricity generation capacity and the high degree of dependence on nuclear energy.

Belgium is rated generally low for both of the energy demand factors (Factor 4 and 5). Although a moderate level of total energy is currently used in the residential/commercial sector, this use has been decreasing since 1978 and is not expected to grow over the next fifteen years; similarly, coal's share of this energy has been decreasing and is expected to continue this trend. The lack of growth in this energy sector is reflected in the country's low projected population growth over the next fifteen years. It should be noted that Belgium does have some installed district heating and combined heat and power capacity, the latter of which is entirely coal-fired. Since the residential/commercial sector uses more than twice as much oil as gas, increased use of district heating in the buildings sector could offer opportunities for coal. Belgium was rated "low-medium" for Factor 4.

Although a modest increase in coal's share of energy use in the industrial sector is expected by 2000, total industrial energy use is low and little growth is expected over the next fifteen years. Although coal plays a small role in most of the industry groups that were examined, coal is used extensively in Belgium's cement industry. Overall, however, because of its low current energy use and low growth projections in the industrial sector, Belgium received a "low" rating for Factor 5.

Belgium appears to offer somewhat limited potential as a partner with the United States in advanced coal technology trade. Only five percent of the country's imports are from the United States (although Belgium imports both boilers and coal from the United States). Although advanced coal technology (ACT) manufacturing in Belgium is currently very limited, Belgium is carrying out collaborative research on ACT with both Germany and the Netherlands, and any future Belgian demand for ACT is likely to be filled by imports from those countries or development of a domestic industry.

Environmental pressure for advanced coal technology is fairly minimal (rated "low-medium"). Although the government is aiming for a 30% reduction in SO_2 emissions by 1995, the required reductions can be achieved through fuel switching and increased use of nuclear energy. Proposed emission limits can be achieved through use of low-sulfur coal.

Although a small market for U.S.-developed ACT may exist in Belgium, the overall prospects are limited by the current overabundance of electric power generating capacity, the small increase in projected energy demand, the lack of environmental incentives, and the competition from domestic ACT R&D.

3.2.3.2 Finland

Finland has virtually no indigenous oil, gas, or coal, so must rely on imports to meet much of its demand. About 40% of the primary energy requirement in Finland is met by imported oil; however most of this oil comes from the U.S.S.R. (a fairly secure supply for Finland), leading to a rating of "low-medium" for Factor 2. Energy demand is being met increasingly by nuclear power, which currently supplies 20% of Finland's electricity; nuclear capacity is projected to grow by 50% between 1985 and 2000. Coal is also playing an increasing role in the energy picture. Although coal's share of the country's total primary energy requirement was only 18 percent in 1985, this reflects a significant increase over the 1973 level; moreover, coal imports increased by 66 percent over the same period, and the projected use of coal in 2000 is double the 1985 level. Therefore, Finland's energy situation appears to favor coal in some respects, but its current and projected dependence on nuclear energy suggest that coal will have to compete strongly with electricity in the residential, commercial and industrial sectors.

Current and projected energy use in the residential/commercial and industrial sectors is low. An increase of 5 Mtce over the period 1985-2000 is expected in industry, which currently uses eight times as much oil as gas. However, residential/commercial energy use is expected to decline. Though the coal share of residential/commercial energy is expected to increase substantially by 2000, overall energy requirements are so small that this increase does not translate to a large market for coal combustors. Moreover, the country's urban population is small and population growth is projected to be fairly low. There may be some opportunities for coal in district-heating and combined-heat-and-power applications, especially since the government is promoting such systems. The very small energy demand in the residential/commercial and industrial sectors led to generally low ratings for Factors 4 and 5 for Finland.

Finland does not appear to offer good trade prospects. It imports little from the U.S. (due to its strong relationship with the U.S.S.R.) and has a strong domestic industry in several advanced coal technologies. It is, however, engaged in a cooperative bilateral agreement with the U.S. for energy R&D.

Environmental pressure for advanced coal technology is fairly high in Finland. Existing regulations will require a seventy to eighty percent reduction in SO^2 emissions for larger coal plants, and there is a proposal for mandatory use of low-sulfur coal in other plants.

Although Finland was rated fairly high on several important factors (energy plan/situation and environmental pressure), increased use of nuclear power, low current and projected energy demand in the residential, commercial and industrial sectors, trade constraints, and competition from domestic ACT manufacturers tend to limit the potential for export of U.S.-developed ACT to that country.

3.2.3.3 The Netherlands

The Netherlands has a high level of indigenous natural gas production and uses gas to supply over 30% of its primary energy requirements. (The Netherlands therefore received a "low-medium" rating for Factor 2 -- Oil/Gas Import Dependency). The country also has only a very small domestic oil supply, but it is highly dependent on oil (53% of 1985 primary energy requirement was supplied by oil). The Netherlands is therefore reducing its oil imports. Nuclear energy currently supplies only three percent of generating capacity, and since the Chernobyl accident, the government has postponed consideration of new nuclear plants.

In the meantime, the Netherlands is considering the use of coal-fired plants to meet projected electricity demand. Current use of coal for electricity production is fairly low, and coal supplied only 11 percent of the total primary energy requirement in 1985. Little coal production currently takes place in the Netherlands, though production was considerably higher in the past. In addition, transportation of coal does not appear to be a constraint in the Netherlands; therefore, the country was rated "medium-high" for Factor 3 (Coal Experience). The Netherlands currently relies on coal imports, which have increased by 146% since 1973. The interest in coal in the Netherlands appears to be focused primarily on power generation. Renewable energy sources and combined-heat-and-power are being promoted in the demand sectors. Furthermore, domestically-produced natural gas will provide strong competition to coal in the residential, commercial and industrial sectors; therefore, the Netherlands was rated "low-medium" for Factor 1 (Energy Plan/Situation).

Current and projected energy demand in the Netherlands, as reflected in its ratings for Factors 4 and 5, is "low". Current total residential/commercial demand is moderate, but is projected to decrease by 2000; industrial use is fairly low, with low projected growth. Coal's share of total energy use is low in both sectors; gas in the predominant energy source. The Netherlands does have some installed district-heating and cogeneration capacity, and the government provides subsidies for district heating projects. Although this implies a potential opportunity for coal, coal is not currently used for such projects.

The Netherlands has one of the most open trading environments of all the countries considered, imposing few tariff or non-tariff barriers to U.S. exports. Fourteen percent of the country's 1985 imports were from the U.S., and these imports included coal. Thirty-five percent of total coal imports to the Netherlands in 1986 came from U.S. sources (54% in 1982). Trade relations (Factor 6) were therefore rated "medium-high" in the Netherlands. However, the Dutch government has committed substantial resources to coal R&D and private industry is conducting coal R&D on its own. Moreover, some ACT manufacturing is being carried out in the country. These competition factors tend to offset the Netherlands' otherwise favorable rating on trade.

Environmental pressure for advanced coal technology is fairly high. A strong control program, similar to West Germany's, is in place; limits for smaller plants can be met with low-sulfur coal. Because of the land shortage in the Netherlands, waste disposal is a major issue. Atmospheric fluidized bed combustion (AFB) and integrated combined cycle (IGCC) are already under development in support of coal policy.

The major constraints to export of U.S.-developed ACT to the Netherlands are as follows: an indigenous gas supply; low current and projected energy demand; and competition from domestic ACT suppliers.

3.2.3.4 Sweden

The Swedish Government's energy policy emphasizes replacement of oil and nuclear energy and introduction of new energy technologies based on renewable and indigenous energy sources. Measures to improve the efficiency of electricity use are also promoted in the Swedish energy plan. Although some coal has been imported by Sweden in recent years, the tax on coal has been increased recently, and other energy resources (in particular, use of indigenous fuelwood and peat) are being encouraged much more strongly than coal. Sweden was therefore rated "low-medium" for Factor 1 (Energy Plan/Situation). Although over 30% of the primary energy requirement in 1985 was met by imported oil, most of that came from OECD and centrally-planned economies, and Sweden was rated "low-medium" for Factor 2 (Oil/Gas Import Dependency). Sweden has very little experience with coal, leading to a "low" rating for Factor 3. Only 5% or less of its annual primary energy requirement was met with coal during the 1973-1985 period. Therefore, Sweden is rated fairly low for general energy conditions favoring coal use.

Sweden is also rated fairly low on the energy demand factors (Factors 4 and 5). Residential/commercial energy use is currently moderately low at 20 Mtce, has been decreasing since 1978, and is expected to continue to decrease through 2000. The coal share of residential/commercial energy demand is also low and projected to remain so. However, Sweden does currently have a small amount of coal-fired district heating capacity, and the government is encouraging expansion of that capacity; this changed the otherwise "low" rating for Factor 4 for Sweden to "low-medium". For Factor 5, Sweden was rated "low" due to its low current industrial energy demand, its low coal share across most industrial categories, its decrease in industrial energy demand since 1973, and its low projected increase in energy demand.

Although the United States imports a small amount of coal to Sweden, total U.S. imports comprise only about 7% of all imports to Sweden; therefore Sweden's rating for Factor 6 (Trade Relations) is "low-medium". Sweden has also played a strong leadership role in the development of ACT (particularly AFB) and pollution control technology; it was therefore rated "low-medium" for Factor 7 (Lack of Domestic Competition). Overall, trade opportunities for U.S. ACT appear to be fairly limited in Sweden.

However, the environmental pressure for ACT is rated "high" in Sweden. There is a strong domestic air pollution control program and high environmental awareness. Control of NO_x is a big issue, and demand could be high for U.S.-developed technologies that combine SO_2 and NO_x. Sweden also is strongly interested in fluidized-bed and sorbent-injection systems for small units.

Despite this very positive environmental pressure for advanced technologies, increased use of U.S.-developed ACT in Sweden will be constrained by the low energy demand, the commitment of the government to renewable energy sources instead of coal, the lack of coal experience, and the presence of domestic competition for ACT development in Sweden.

3.3 CONCLUSIONS AND RECOMMENDATIONS

One of the purposes of this analysis was to choose the three OECD countries that appear to have the highest potential as export markets for U.S.-developed ACT for small-combustor applications. Eight of the 24 OECD countries were not examined in depth because of their very low current and projected energy demand. The methodology employed to rate the remaining fifteen countries led to the grouping of the countries into three categories. Category 1 (Countries With Good Potential Markets) includes Italy, Spain, Turkey, Greece, and Canada.

The in-depth analysis carried out for these countries found that no serious impediments exist in Italy and Spain. In Turkey, coal-transportation problems could slightly hamper a rapid and extensive increase in coal use. However, the attitude toward coal and the high levels of energy growth projected for Turkey appear to be so overwhelmingly favorable that Turkey is viewed as a very good potential market for U.S. ACT. Greece and Canada, although promising in many respects, do not appear to be as favorably disposed to increased use of ACT as Turkey. Canada has a broad spectrum of energy options -- coal, oil, gas, nuclear, and hydropower -- from which to choose, and therefore coal is not being very heavily promoted. The energy situation and factors driving conversion to coal in Greece are very similar to those in Turkey; however, current and projected energy demand in Greece is much lower than in Turkey. Therefore, it is recommended that the next phase of study be directed toward Italy, Spain, and Turkey.

4 REFERENCES

1. International Energy Agency, Energy Policies and Programmes of IEA Countries, 1986 Review, Organization for Economic Co-operation and Development, Paris, 1987.

2. International Energy Agency, Coal Information 1987, Organization for Economic Co-operation and Development, Paris, 1987.

3. International Energy Agency, Energy Statistics, 1970/1985, Organization for Economic Co-operation and Development, Paris, 1987.

4. International Energy Agency, Energy Balances of OECD Countries, 1970/1985, Organization for Economic Co-operation and Development, Paris, 1987.

5. International Energy Agency, Coal Prospects and Policies in IEA Countries: 1983 Review, Organization for Economic Co-operation and Development, Paris, 1984.

6. International Energy Agency, District Heating and Combined Heat and Power Systems, A Technology Review, 1983, Organization for Economic Co-operation and Development, Paris, 1983.

7. International Energy Agency, Quarterly Oil and Gas Statistics, Organization for Economic Co-operation and Development, Paris, 1987.

8. International Energy Agency, Clean Coal Technology Programmes and Issues, Organization for Economic Co-operation and Development, Paris, 1987.

9. Coal Advisory Board, Environmental Strategies for Coal Use, International Energy Agency, Organization for Economic Co-operation and Development, Paris, 1985.

10. Organization for Economic Co-operation and Development, Coal: Environmental Policies and Institutions, Paris, 1987.

11. Jan Vernon, Coal Research, personal communication International Energy Agency, London.

12. World Bank, World Development Report 1986, Washington, D.C. 1986.

13. Agency for International Development, Countries of the World Yearbook, 1988.

14. Energy Information Administration, International Energy Annual 1986, U.S. Department of Energy Report DOE/EIA-0219(86).

15. U.S. Department of Commerce, "Foreign Economic Trends" reports for the various countries.

16. U.S. Department of Commerce, "Overseas Business Report" for the various countries.

APPENDICES

APPENDICES

The following eight appendices present the background data and information used to rate each country for each factor. The first few pages of each appendix contain summarized information for each country that justifies the country's rating for the factor. This summary is followed by one or more tables that present for all fifteen countries information pertinent to the questions guiding the ratings. A list of the acronyms used in the appendices can be found on the next page.

List of Acronyms

(to be provided)

APPENDIX 1

ENERGY PLAN/SITUATION
(Factor 1)

APPENDIX 1

Energy Plan/Situation: Factor 1
COUNTRY SUMMARIES

Australia: HIGH

- Government wants to use indigenous resources, especially coal and natural gas.
- High coal production (117 Mtce) in 1985 (about half was met. coal). More than doubling of coal production over the period 1973-1985.
- Fairly high non-met. coal consumption (37 Mtce in 1985).
- No imports; abundant indigenous coal reserves.
- No actual or projected nuclear power.

Belgium: LOW-MEDIUM

- Nuclear supplies 38% of electric generating capacity and is projected to increase. Country currently has excess electric generating capacity.
- Coal conversion encouraged in all economic sectors; "rational energy use" objectives include coal.
- Some domestic coal production (7 Mtce) in 1985, but production declined by 28% over 1973-1985.
- Domestic coal industry subsidized; coal taxed at lower rate than other fuels and electricity.
- Some coal imports in 1985 (9 Mtce), and an 11% increase in imports over last decade. About 70% of steam coal used in 1985 was imported.
- S. Africa is a major source of coal imports.

Canada: MEDIUM-HIGH

- Moderately high 1985 coal production (48 Mtce); more than doubling of production over last decade. About half of coal production in 1985 was metallurgical coal. About 5 Mtce of steam coal was exported.
- Some steam coal imports (from the U.S.).
- Fairly high level of steam coal use (30 Mtce).
- Varied energy sources. Hydro provides a large portion of electricity. Some nuclear power (12% of electricity generating capacity). Wood provides a significant amount of industrial energy demand.
- Energy plan does not specifically promote coal.

Finland: MEDIUM-HIGH

- Finland's projected use of coal in 2000 is twice the 1985 level.
- 66% increase in coal imports over 1973-1985.
- 20% of electricity generating capacity is nuclear, and

nuclear capacity is projected to grow by over 50%.
- Energy plan not available. (Finland is not a member of IEA.)

France: LOW-MEDIUM

- High current and projected nuclear capacity in utility sector; current oversupply of electric generating capacity.
- High increase in electricity use projected for res/com/ind sectors.
- France's projected total use of coal in 2000 is about the same as that in 1985, but projected use in 2000 in res/comm/ind sectors is 62% higher than 1985.
- Moderate level of coal production (15 Mtce in 1985),40% decrease in production over last decade. There is some political pressure to restore coal production to previous levels.
- Moderate level of coal imports (17 Mtce); 30% increase in imports over last decade. France no longer accepts S. African imports.
- Energy plan not available. (France is not a member of IEA.)

Federal Republic of Germany: MEDIUM-HIGH

- Increasing role of coal in energy mix is a policy objective.
- Highest coal producer of all countries considered; second-highest steam-coal producer. There has been a slight decrease in production over last decade.
- Moderately high coal imports, increase in imports over last decade.
- Domestic hard coal industry subsidized.
- Nuclear plants supplied about 17% of electric generating capacity in 1985; nuclear energy production expected to increase.

Greece: HIGH

- Policy favors use of imported coal to reduce oil import dependency and encourages increased use of domestic lignite. Government policy and R&D also encourage renewables.
- Some domestic coal production (7 Mtce) in 1985, tripling of production over last decade.
- Low level of coal imports (2 Mtce in 1985), but doubling of imports since 1973 (primarily for the cement industry).
- Oil products taxed more heavily than other fuels.
- No current or planned nuclear generation.

Italy: MEDIUM-HIGH

- Increase in coal consumption called for in National Energy Plan to come mostly from steam coal for power generation.
- Low coal production (< 1 Mtce in 1985), but 60% increase in production over last decade.

- Second highest importer of coal in 1985 of countries considered (20 Mtce), 85% increase in imports since 1973.
- S. Africa is largest source of coal imports.
- Nuclear supplied only 2% of generating capacity in 1985, will probably not increase much based on recent national non-nuclear referendum.

Japan: LOW-MEDIUM

- A balanced energy mix, including coal, is a major objective. Hydropower and renewables are encouraged.
- Moderate level of coal production (14 Mtce in 1985); decrease in production over last decade.
- Largest importer of coal in 1985 of countries considered (primarily for iron and steel industry), some increase in imports over last decade.
- Nuclear is biggest source of indigenous energy supply; hydro is second. Country moving toward increased nuclear power production. Renewables encouraged.

The Netherlands: LOW-MEDIUM

- Major natural gas producer.
- Coal conversion promoted in electricity generation sector only. Priority placed on renewables and combined heat and power.
- Low coal production, but moderately high coal imports (12 Mtce in 1985) and an increase in coal imports of 146% since 1973.
- Nuclear supplies only 3% of generating capacity.

Portugal: HIGH

- Government stresses importance of coal as a primary energy source.
- Low coal production (< 1 Mtce in 1985), and a 26% decrease in production from 1973 to 1986.
- Low imports in 1985 (0.5 Mtce), but high increase in imports between 1973 and 1986 (1.8 Mtce in 1986), mostly from the U.S.
- Fuel oil subsidized.

Spain: HIGH

- Government is making an effort to substitute coal for oil in industry and in urban areas.
- Moderately high 1985 coal production (20 Mtce), high increase in production (111%) over 1973-1985.
- Moderate level of coal imports (8 Mtce), large increase in imports over 1973-1985 (152%).
- Large amount of coal imported from S. Africa.
- New, coastal-sited electric power plants are designed for

imported coal.

Sweden: LOW-MEDIUM

- No policies to encourage coal in energy plan. Use of domestic fuel wood and peat are encouraged.
- Almost no coal production.
- Moderate level of coal imports (5 Mtce in 1985); 97% increase in imports over 1973-1985.
- Coal tax recently increased.
- All nuclear plants being phased out.

Turkey: MEDIUM-HIGH

- "Optimum" energy production from lignite is included in goals, along with diversification of energy sources. Renewables are being encouraged.
- Moderate coal (mostly lignite) production (13 Mtce), high increase (78%) in production between 1973 and 1985.
- Moderately low coal imports, but imports have increased from 10,000 tons in 1973 to an estimated 3 million tons in 1986. (Imports come primarily from the U.S..)

United Kingdom: MEDIUM-HIGH

- High 1985 coal production (77 Mtce); almost all of production is steam coal. A 29% decrease in production between 1973 and 1985.
- Moderately high coal imports, with large increase in imports over 1973-1985 (1.6 million tons to 12.9 million tons), most of imports are met. coal, primarily from Australia.
- Free-market policy for energy.

Table 1.1A Government Policies Regarding Coal Use: Energy Plan

	Does the energy plan of the country state that increased coal use is a primary goal?
Australia	The government is concerned with making the best use of the country's indigenous resources, particularly coal and natural gas.
Belgium	Energy policy objectives include "rational use of energy" which includes coal; government will provide subsidies of up to 100% for "rational use" development projects. Coal conversion generally encouraged in all economic sectors.
Canada	Canada's energy policy stresses self-sufficiency energy security, increased energy efficiency. It does not contain specific provisions encouraging coal.
Finland	Information not available.
France	Information not available.
FRG	One objective is to reduce the share of oil in the energy supply and increase the role of all other energy sources, especially domestic coal. Nuclear plays fairly large role.
Greece	Main goal is to reduce dependence on imported oil; one avenue for this is through use of imported coal.
Italy	The National Energy Plan calls for an increase in coal consumption, mostly steam coal for power generation.
Japan	A balanced energy mix, including coal, is a major objective.
Netherlands	Government is promoting coal conversion in the electricity generation sector.
Portugal	Government stresses importance of coal as a primary energy source.
Spain	A special effort is being undertaken to substitute coal for oil in industry and in urban areas.
Sweden	Measures for replacement of oil and nuclear have been enacted by law. Phase-out strategy based on renewables and indigenous energy resources.
Turkey	"Optimum" energy production from lignite is included in goals, as is diversification of energy sources. Turkey signed an agreement with the USSR in 1984 to buy natural gas and a new pipeline to Anhara is under construction.
UK	U.K. has no centralized energy plan. General policy is to ensure adequate and secure energy supplies at lowest long-term cost.

Source: IEA, Energy Policies and Programmes of IEA Countries, 1986 Review

Table 1.1B Government Policies Regarding Coal Use: Renewables and Other Energy Sources

	Is the country currently reliant on any indigenous renewable or unusual energy resources? Are any of these indigenous renewable/unusual sources being heavily promoted in the energy plan?
Australia	12% of electricity is from hydropower. Role of other renewables is small, not heavily promoted.
Belgium	Not currently heavily reliant on renewable energy. 18.1% of government energy R&D spending in 1985 was for "other" energy sources (solar photovoltaic, wind, microhydro and biomass) as opposed to 9.3% for coal.
Canada	Biomass (mostly wood) accounted for 14.5% of total industrial energy demand in 1985. Hydropower accounts for almost all electricity generation in Quebec and British Columbia and 66.2% of electricity country-wide. Other renewable sources not heavily promoted.
FRG	Not currently reliant on renewable sources. Renewables accounted for 11.6% of 1986 energy budget.
Greece	Not currently reliant on renewable sources. Policy emphasizes switch away from imported oil for electricity generation through increased use of domestic lignite, renewables, and hydro. 63.2% of 1986 energy budget was for renewables.
Italy	24% of electricity from hydropower. Geothermal energy expected to play larger role in electricity generation.
Japan	Hydroelectric power follows nuclear as the biggest source of indigenous energy supply (33GW capacity in 1986). Hydropower promoted by government. Renewable sources such as solar and wind encouraged but claim a small share of the energy budget (4.3% in 1986.)
Netherlands	Not currently reliant on renewable energy. Government places priority on development of renewables, particularly wind, and combined heat and power.
Portugal	Not currently reliant on renewable energy, although it is a priority area for government energy RD&D funding.
Spain	Not currently reliant on renewable energy. Renewables received 27.6% of the 1986 energy budget.
Sweden	Domestic fuelwood and peat contributed 5.3 Mtoe in 1985. Efforts to develop these resources further are being carried out. Renewables received 21.0% of energy budget in 1986.
Turkey	Fuel wood and animal dung are used extensively in rural areas. Major hydroelectric development program underway. Budget allocation for solar, geothermal and biomass more than doubled during 1983-1986.
U.K.	Not currently reliant on renewable sources and renewables not heavily promoted.

Source: IEA, Energy Policies and Programmes of IEA Countries, 1986 Review.

Table 1.1C Government Policies Regarding Coal Use: Fuel Taxes/Subsidies

	Does the government alter in any way the market price of any fuel?
Australia	Government enforces import parity pricing of crude oil. Fossil fuel production taxed by states. Natural gas prices partially controlled by states.
Belgium	Imported coal priced at world market level; higher cost Belgian coal subsidized and guaranteed market share. The VAT rate applied to other fuels and electricity is 17%, while it is 6% for coal.
Canada	Coal prices market-determined. Crude oil and natural gas prices deregulated in June 1985.
Finland	Information not available.
France markets.	Indigenous coal prices heavily subsidized ans assured
FRG	Energy pricing generally free of government intervention. Coal levy applies to imports of metallurgical coal. Domestic hard coal industry subsidized and assured market share.
Greece	Energy product prices set by state; heavier taxes on oil products.
Italy	Coal prices unregulated. Electricity and natural gas for residential/commercial sector regulated. Petroleum product prices regulated, monitored, or free.
Japan	Indigenous coal prices fixed by government and coal is assured markets: imported coal prices market-determined. Electricity and town gas tariffs need government approval.
Netherlands	Coal prices reflect world market. Oil product prices freely determined; gas and electricity regulated.
Portugal	Coal prices unregulated; petroleum product prices and electricity rates controlled by government; fuel oil subsidized.
Spain	Most prices controlled by government and specific energy taxes used for policy reasons. Coal prices unregulated for residential/commercial and non-metallurgical industrial uses.
Sweden	Imported coal at world market prices. Domestic prices reflect production and distribution costs. Coal tax has recently been increased.
Turkey	Metallurgical coal imports at world market level. Residential lignite priced below average production cost; industrial lignite priced above it. Petroleum (except LPG) at world market level. Electricity prices controlled by government.
UK	Britsh coal is a nationalized industry; coal prices are set by the government and domestic coal production is subsidized.

Source: IEA, Energy Policies and Programmes of IEA Countries, 1986 Review

Table 1.2 Historical Coal Production in OECD Countries

Country	Coal Production (Mtce)			Percent Change, 1973-1985
	1973	1978	1985	
Australia	57.50	70.04	117.20	+ 103.8
Belgium	9.17	6.77	6.61	- 27.9
Canada	16.71	24.46	48.20	+ 188.5
Finland	-	-	-	-
France	25.77	20.11	15.37	- 40.4
FRG	131.91	121.23	117.77	- 10.7
Greece	2.41	3.97	6.91	+ 186.7
Italy	0.43	0.43	0.69	+ 60.5
Japan	25.57	15.97	13.74	- 46.3
The Netherlands	1.80	-	0.1	- 94.4
Portugal	0.19	0.10	0.14	- 26.3
Spain	9.26	11.10	19.56	+ 111.2
Sweden	-	0.0	0.0	-
Turkey	7.44	10.04	13.23	+ 77.8
UK	108.41	98.94	76.71	- 29.2

Source: IEA, Coal Information 1987.

Table 1.3 Indigenous Supply of Non-Metallurgical Coal, 1985

INDIGENOUS SUPPLY OF NON-METALLURGICAL COAL, 1985
(Mtce)

	Non-Metallurgical Coal Use*	Non-Metallurgical Coal Production	Non-Metallurgical Coal Exports	% Non-Metallurgical Coal Use From Indigenous Sources
Australia	37.2	63.39	29.15	92
Belgium	7.4	3.13	0.84	31
Canada	30.6	25.05	4.64	66.7
Finland	1.5	-	0.01	-
France	23.7	11.98	0.81	47.1
FRG	94.3	67.15	3.47	67.5
Greece	8.7	6.91	0.21	77.0
Italy	12.6	0.69	-	5.5
Japan	41.4	9.64	-	23.3
The Netherlands	6.1	–	1.23	-
Portugal	0.8	0.14	-	17.5
Spain	22.6	18.61	-	82.3
Sweden	2.5	-	-	0.0
Turkey	11.0	11.40	-	(100)
U.K.	76.4	74.19	2.17	94.3

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* Final consumption plus electric-utility consumption minus consumption in the iron and steel industry.

Source: IEA, Coal Information 1987.

Table 1.4 Coal Imports to OECD Countries, 1973-1986

Country	Coal Imports (Mtce) 1973	1979	1983	1984	1985	1986(e)	% Change, 1973-1985	Avg. Annual % Change 1983-1985
Australia	-	0.01	-	-	-	-	-	-
Belgium	7.60	6.87	7.19	9.43	9.30	8.43	+10.9	+14.9
Canada	14.96	14.19	15.10	18.24	14.49	13.76	- 3.1	+ 0.0
Finland	3.49	5.23	5.06	4.43	5.80	6.00	+66.2	+ 9.2
France	15.43	23.54	18.87	22.21	20.01	17.26	+29.7	+ 3.9
FRG	9.71	8.43	12.09	12.06	12.70	12.84	+30.8	+ 2.6
Greece	0.67	0.40	1.26	1.69	1.97	1.73	+194.0	+25.4
Italy	11.67	12.91	16.96	19.91	21.63	20.13	+85.3	+13.0
Japan	59.0	52.67	75.36	87.23	92.73	89.11	+57.0	+11.1
The Netherlands	4.66	5.57	7.79	11.13	11.47	12.10	+146.1	+23.5
Portugal	0.40	0.51	0.53	0.53	1.51	1.84	+277.5	+92.5
Spain	3.09	3.70	5.76	6.66	7.77	7.63	+151.5	+16.2
Sweden	2.41	1.87	3.06	3.86	4.74	4.36	+96.7	+24.5
Turkey	0.01	0.46	1.53	1.99	2.67	3.06	+266.0	+32.2
U K	1.60	2.19	5.13	10.89	12.89	10.64	+705.6	+65.4

(e) = estimated.

Source: IEA, Coal Information 1987.

Table 1.5 Principal Sources of Steam Coal Imports, 1985

Country	Sources and Quantities (10^3 Metric Tons) of Imports	
Australia	--	--
Belgium	Australia	205
	China	112
	FRG	1067
	S. Africa	2078
	US	671
Canada	US	8391
Finland	Australia	404
	US	1018
	Poland	2407
	USSR	852
	Colombia	347
France	Australia	850
	US	678
	Canada	410
	Czechoslovakia	883
	Germany	1134
	S. Africa	6444
	UK	204
FRG	Australia	720
	Canada	235
	US	1072
	UK	180
	Czechoslovakia	346
	Poland	2709
	USSR	166
	S. Africa	3196
Greece	Australia	588
	US	1136
	S. Africa	207
Italy	Australia	250
	US	3518
	Czechoslovakia	1150
	USSR	150
	S. Africa	6641
	Colombia	180
Japan	Australia	14137
	Canada	780
	US	960
	USSR	1020
	China	2426
	S. Africa	4091

Table 1.5 Principal Sources of Steam Coal Imports, 1985 (cont.)

Country	Sources and Quantities (10^3 Metric Tons) of Imports	
The Netherlands	Australia	1755 2
	Canada	130
	Germany	143
	US	2872 1
	Poland	878
	S. Africa	812
	Colombia	150
Portugal	UK	111
	US	669 1
	S. Africa	104
Spain	Australia	407
	Canada	173
	U.S.	855 2
	Poland	379
	S. Africa	2243 1
	Colombia	134
Sweden	Australia	603 2
	US	343
	Poland	1271 1
	USSR	407
	Colombia	183
Turkey	US	275
UK	Australia	2469 1
	Germany	746 2
	US	498
	Poland	258
	S. Africa	724

Source: IEA, Coal Information 1987.

Table 1.6 Nuclear Electricity Generating Capacity, 1985

* Country	Nuclear Capacity (MW)	Total Capacity (MW)	Nuclear Fraction of Capacity (%)
Australia	—	32695	—
Belgium	5425	14112	38.4
Canada	11159	97356	11.5
Finland	2300	11313	20.3
France	37487	86562	43.3
FRG	16095	92701	17.4
Greece	—	7116	—
Italy	1273	55626	2.3
Japan	24686	169358	14.6
Netherlands	508	16991	3.0
Portugal	—	6010	—
Spain	5815	39205	14.8
Sweden	9455	33168	28.5
Turkey	—	9118	—
UK	7064	67607	10.4

* Net maximum capacity as of 12/31/85.

Source: IEA, Energy Statistics, 1970-1985.

Table 1.7 Current and Projected Nuclear Generating Capacity

	Nuclear Generating Capacity (GW)		
Country	1985	2000	% Change 1985-2000
Australia	-	-	-
Belgium	5.4	6.8	+ 25.9
Canada	11.2	17.6	+ 57.1
Finland	2.3	3.6	+ 56.5
France	37.5	78.0	+ 108.0
FRG	16.1	25.6	+ 59.0
Greece	-	-	-
Italy	1.3	9.1	+ 600.0
Japan	24.7	62.0	+ 151.0
The Netherlands	0.5	3.0	+ 500.0
Portugal	-	0.9	-
Spain	5.5	10.4	+ 89.1
Sweden	9.5	8.5	- 10.5
Turkey	-	0.6	-
UK	7.1	18.0	+ 153.5

Source: IEA, Coal Information 1987.

Table 1.8 Role of Electricity in the Demand Sectors In Countries with High Nuclear Generation[a]

Percentage of Total Residential/Commercial/Industrial[b]
Energy Use Supplied by Electricity,
1985 and 2000

Country	% of Total Residential, Commercial and Industrial Energy Use Supplied by Electricity	
	1985	2000
Belgium	16.9	21.0
Finland	25.4	31.0*
France	21.6	35.6
FRG	19.9	22.7*
Italy	18.5	29.4*
Japan	27.7	29.9*
The Netherlands	12.7	14.7
UK	20.7	24.1

[a] Countries which had a high percentage of nuclear-generated electricity in 1985 and/or projected high growth in nuclear-generated electricity during 1985-2000. Sweden is excluded because all nuclear power plants are scheduled to be phased out by 2000.

[b] Excluding energy use in the iron and steel industry.

* Projected industry-specific electricity use not available; may include use in iron and steel industry.

Source: IEA, Coal Information 1987

APPENDIX 2

OIL/GAS IMPORT DEPENDENCY
(Factor 2)

APPENDIX 2

Oil/Gas Import Dependency: Factor 2
COUNTRY SUMMARIES

Australia: LOW

- Less than 1% of total primary energy requirement (TPER) met by oil imports in 1985, down from 15% in 1979.
- Moderate levels of indigenous oil and gas.

Belgium: MEDIUM-HIGH

- 45% of TPER met by oil imports in 1985.
- Moderately high imports from U.S.S.R., low imports from OPEC.
- No indigenous oil, minimal gas.

Canada: LOW

- Net exporter of petroleum.

Finland: LOW-MEDIUM

- 40% of 1985 TPER met by oil imports.
- U.S.S.R. is primary source of oil imports, very little imported oil from OPEC.
- No indigenous oil or gas.

France: MEDIUM-HIGH

- 41% of 1985 TPER met by oil imports.
- Significant oil imports from OPEC and centrally planned economies.
- 24% of natural gas use in 1985 met by imports from the U.S.S.R..
- Some indigenous oil and gas.

Federal Republic of Germany: LOW-MEDIUM

- 40% of 1985 TPER met by oil imports, but most imports come from OECD.
- 29% of natural gas used in 1985 met by imports from the U.S.S.R..
- Moderate level of indigenous gas.

Greece: HIGH

- 58% of 1985 TPER met by oil imports, down from 91% in 1973.
- Large portion of oil imports come from centrally-planned economies.

- Minimal indigenous oil and gas.

Italy: HIGH

- 59% of 1985 TPER met by oil imports, down from 79% in 1973.
- Significant oil imports from OPEC and centrally planned economies.
- 22% of natural gas used in 1985 met by imports from the U.S.S.R.
- Moderate level of indigenous gas.

Japan: HIGH

- 57% of 1985 TPER met by oil imports, down from 82% in 1973.
- A large portion of oil imports are from OPEC.
- Minimal amount of indigenous oil and gas.

The Netherlands: LOW-MEDIUM

- 40% of 1985 TPER met by oil imports, down from 65% in 1973.
- Significant oil imports from OPEC and centrally planned economies (as well as OECD).
- High level of indigenous gas production.

Portugal: MEDIUM-HIGH

- 67% of 1985 TPER met by oil imports, and the level of imports has not changed much since 1973.
- Most oil imports are from OECD.
- No indigenous oil or gas.

Spain: HIGH

- 53% of 1985 TPER met by oil imports, down from 72% in 1973.
- Minimal indigenous crude oil and gas production.
- Crude oil imports come primarily from OPEC countries.

Sweden: LOW-MEDIUM

- 31% of 1985 TPER met by oil imports, down from 61% in 1973.
- Practically no indigenous gas or oil production in 1985.
- Most oil imports come from OECD and centrally-planned economies.

Turkey: MEDIUM-HIGH

- 38% of 1985 TPER met by oil imports.
- Oil imports have increased slightly between 1973 and 1985.
- Substantial portion of diesel oil imports come from OPEC and U.S.S.R.
- Minimal amount of indigenous oil production; no gas.

United Kingdom: LOW

- Net petroleum exporter in 1985.

Table 2.1 Oil Imports as a Percentage of Total Primary Energy Demand (TPER)

	TPER (Mtoe*)			NET OIL IMPORTS (Mtoe*)			% of TPER MET BY OIL IMPORTS		
	1973	1979	1985	1973	1979	1985	1973	1979	1985
Australia	59.5	71.4	77.9	9.2	10.9	0.6	15.5	15.3	0.8
Belgium	46.2	47.9	42.8	30.9	29.0	19.2	66.9	60.5	44.9
Canada	178.8	220.3	233.2	-14.0	7.7	-17.5	0.0	3.5	0.0
Finland	22.8	25.3	27.0	13.9	14.9	10.8	61.0	58.9	40.0
France	179.7	194.2	197.2	129.7	122.0	81.5	72.2	62.8	41.3
FRG	266.2	286.5	268.5	146.8	147.1	108.1	55.1	51.3	40.3
Greece	12.5	16.3	18.4	11.4	13.1	10.6	91.2	80.4	57.6
Italy	132.3	144.7	140.2	104.5	100.4	82.4	79.0	69.4	58.8
Japan	338.9	372.2	375.6	277.5	281.8	214.4	81.9	75.7	57.1
The Netherlands	63.2	69.9	62.1	41.3	41.6	24.9	65.3	59.5	40.1
Portugal	8.2	11.4	12.8	6.2	9.1	8.6	75.6	79.8	67.2
Spain	55.5	72.4	74.3	40.2	49.1	39.3	72.4	67.8	52.9
Sweden	47.3	51.3	55.0	28.8	29.2	17.2	60.9	56.9	31.3
Turkey	24.5	32.1	39.7	8.7	11.6	15.1	35.5	36.1	38.0
UK	220.8	220.0	202.8	115.7	19.2	-50.5	52.4	8.7	0.0

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* Million tons of oil equivalent = approx. 20 ×10[illegible] btu ≈ 0.7× million tons of coal equivalent.

Sources: IEA, *Energy Policies and Programmes of IEA Countries*, 1986.
IEA, *Energy Balances of OECD Countries, 1970-1985*, for Finland and France.

Table 2.2 Top Crude Oil Importers: Principal Sources of Crude Oil Imports, 1985

Country	Total Crude Imports (10^3 metric tons)	Main Sources of Crude Imports and Quantities Imported (10^3 Metric tons)	
France	67,043	U.K.	14,897
		Total OECD	19,737
		OPEC	35,166
		U.S.S.R.	2,970
		Total CPE*	3,070
		Non-OPEC Africa	5,773
FRG	64,193	U.K.	17,218
		OECD	20,884
		OPEC	35,016
		U.S.S.R.	3,886
Italy	63,551	U.K.	3,289
		Total OECD	3,406
		OPEC	37,310
		CPE*	5,844
		Non-OPEC Africa	7,640
		Asia	7,575
Japan	164,798	Australia	1,746
		OPEC	119,522
		China	10,953
		Total CPE	11,084
		Asia	23,306
Netherlands	37,394	U.K.	10,409
		Total OECD	13,137
		OPEC	18,123
		U.S.S.R.	2,179
Spain	43,467	U.K.	1,462
		Total OECD	1,793
		OPEC	25,461
		Non-OPEC Africa	4,964
		CPE*	1,230
United Kingdom	26,596	Norway	10,959
		Total OECD	11,971
		OPEC	10,872

*Centrally-planned economies.

Source: IEA, Annual Oil and Gas Statistics, 1984/1985.

Table 2.3 Primary Sources of Petroleum Product Imports, 1986

SOURCES AND QUANTITITES (10^3 METRIC TONS) OF OIL PRODUCT IMPORTS

Country	Gas/Diesel Oil		Residual Fuel Oil	
Australia	OPEC	166	OPEC	448
	Singapore	499	Singapore	418
	Centrally planned economies (CPE)	20	U.S.	312
	U.S.	80		
Belgium	Netherlands	3566	Netherlands	1065
	UK	192	OCED Total	3496
	OPEC	84	OPEC	176
	USSR	979	USSR	1016
Canada	UK	751	US	119
	OPEC	232	OPEC	749
Finland	USSR	1419	USSR	2083
France	Italy	1456	Italy	206
	UK	1093	OECD Total	655
	OECD Total	4827	OPEC	153
	OPEC	2463	USSR	67
	USSR	1455		
	CPE Total	2382		
FRG	Netherlands	12,339	Belgium	1060
	UK	1,729	Netherlands	2290
	OECD Total	18,286	OECD Total	5152
	OPEC	1,941	OPEC	656
	USSR	3080	USSR	1492
	CPE Total	5567	CPE Total	3446
Greece	Italy	65	OECD	123
	OPEC	127	OPEC	298
	USSR	170	USSR	52
	CPETotal	893		
Italy	OECD	468	OECD	1413
	OPEC	2096	OPEC	4781
	USSR	559	USSR	70
	CPE Total	2369	CPE Total	364
Japan	UK	573	UK	1679
	OPEC	530	OPEC	2927
	China	292	USSR	214
	USSR	467	CPE Total	446
Netherlands	UK	1030	Belgium	1413
	OECD Total	3537	OECDq	3114
	OPEC	2912	OPEC	1495
	USSR	4629	USSR	2424
	CPE Total	4965	CPE Total	2592
Greece	Italy	65	OECD	123
	OPEC	127	OPEC	298
	USSR	170	USSR	52
	CPE Total	893		

66
68

Table 2.3 Primary Sources of Petroleum Product Imports, 1986 (cont.)

SOURCES AND QUANTITITES (10^3 METRIC TONS) OF OIL PRODUCT IMPORTS

Country	Gas/Diesel Oil		Residual Fuel Oil	
Italy	OECD	468	OECD	1413
	OPEC	2096	OPEC	4781
	USSR	559	USSR	70
	CPE Total	2369	CDE Total	364
Japan	UK	573	UK	1679
	OPEC	530	OPEC	2927
	China	292	USSR	214
	USSR	467	CPE Total	446
The Netherlands	UK	1030	Belgium	1413
	OECD Total	3537	OECD	3114
	OPEC	2912	OPEC	1495
	USSR	4629	USSR	2424
	CPE Total	4965	CPE Total	2592
Portugal	OECD	48	OECD	1121
Spain	OECD	334	OECD	316
	USSR	144	USSR	275
	CPE Total	292		
Sweden			UK	690
	OECD	1375	OECD Total	1809
	USSR	635	USSR	444
	CPE Total	1128	CPE Total	778
Turkey			Non-OPEC Middle East	121
	OPEC	230		
	USSR	209		
UK	Netherlands	420	Spain	1005
	OECD Total	676	OECD Total	3721
	USSR	704		

Source: IEA, Quarterly Oil and Gas Statistics, 3rd Quarter 1987.

7
66

Table 2.4 Natural Gas Consumption and Imports from the U.S.S.R., 1985

Countries Importing Gas from the USSR	Total Primary Energy Requir. (TPER) (Mtce)	Natural Gas Consumption (Mtce)	Natural Gas Imports from USSR (Mtce)	% TPER Met By Gas Imports from USSR	% Gas Use Met By USSR Imports
France	281.7	35.8	8.7	3.1	24.3
FRG	383.6	59.2	17.1	4.5	28.8
Italy	200.3	39.6	8.5	4.2	21.5

Source: Energy Information Administration, International Energy Annual 1986, U.S. Department of Energy Report DOE/EIA-0219 (86), October 1987.

Table 2.5 Domestic Oil and Gas Production, 1985

Country	Crude Oil Production (10^3 metric tons)	Natural Gas Production (10^3 Tcal)
Australia	25.0	125.0
Belgium	-	0.4
Canada	65.1	765.5
Finland	-	-
France	2.6	50.0
FRG	4.1	134.3
Greece	1.3	0.8
Italy	2.4	128.2
Japan	0.5	21.8
The Netherlands	3.7	678.0
Portugal	-	-
Spain	2.2	2.6
Sweden	0.0	-
Turkey	2.1	0.5
U.K.	122.4	396.9

Source: IEA, Energy Statistics 1970/1985.

9
68

APPENDIX 3

COAL EXPERIENCE
(Factor 3)

APPENDIX 3

Coal Experience: Factor 3
COUNTRY SUMMARIES

Australia: HIGH

- 40% of total primary energy requirement (TPER) supplied by coal in 1985, 38% in 1973.
- Fairly high electricity production from coal in 1985, moderately high in 1973; no nuclear power.
- Adequate transportation infrastructure, expansion continuing.

Belgium: MEDIUM-HIGH

- Share of TPER supplied by coal around 21-24%, 1973-1985.
- Low but increasing use of coal for electricity production since 1973.
- High level of coal production in the past (1950's and 1960's).
- Good transportation infrastructure.

Canada: MEDIUM-HIGH

- 11% of TPER met by coal in 1985, 9% in 1973.
- Substantial amount of coal-fired electricity generating capacity.
- Good transportation infrastructure.

Finland: LOW-MEDIUM

- Coal's share of TPER ranging from 11% to 18%, 1973-1985.
- Low electricity production from coal; increasing use of nuclear power.
- Moderately low port capacity; no data on transport networks.

France: MEDIUM-HIGH

- Decrease in coal's share of TPER, 1973-1985; 12.6% in 1985.
- Moderately high coal-generated electricity (highest in 1978); very large increase in nuclear power over 1973-85 period.
- Moderately high port capacity, with planned additions; no data on transport networks.
- Higher levels of coal production in the past.

Federal Republic of Germany: HIGH

- Coal's share of TPER around 28-32%, 1973-1985.
- High and increasing use of coal for electricity production

(highest of all countries considered).
- Moderately low port capacity, but expansion planned; adequate transport networks.

Greece: LOW-MEDIUM

- Coal's share of TPER was 17% in 1973, 33% in 1985.
- Low use of coal for electricity production in 1973 and 1978; moderately low in 1985; no nuclear power.
- Low port capacity; inadequate transport networks as of 1983.

Italy: LOW-MEDIUM

- Coal's share of TPER was 6% in 1973, 11% in 1985.
- Coal use for electricity production was low in 1973, moderately low relative to other countries in 1985, but greatly increased over 1973 level.
- Moderately high port capacity; transport of coal to coastal sites probably adequate, but inland transport network probably not.

Japan: MEDIUM-HIGH

- Coal's share of TPER around 17-20%, 1973-1985.
- Moderately high electricity production from coal, 1973-1985; large increase in coal-generated electricity since 1973.
- Very high port capacity, with planned expansion; adequate inland transport networks.
- Extensive experience handling metallurgical coal shipments.

Netherlands: MEDIUM-HIGH

- Coal's share of TPER was 5% in 1973, 11% in 1985 .
- Low use of coal for electricity production in 1973 and 1978, moderately low in 1985.
- Considerably higher coal production in the past (1950's-1960's).
- High port capacity, excellent inland transportation infrastructure.

Portugal: LOW

- Coal's share of TPER around 6% or less, 1973-1985.
- Very low electricity production from coal.
- Coal transportation infrastructure not in place as of 1983.

Spain: MEDIUM-HIGH

- Coal's share of TPER was 16% in 1973, 26% in 1985.
- Moderately high and increasing use of coal for electricity production.

- Moderately high port capacity, with planned expansion; existing railways sufficient for domestic coal production as of 1983.

Sweden: LOW

- Coal's share of TPER 5% or less, 1973-1985.
- Very low electricity production from coal.
- Moderately low port capacity, adequate transport networks.

Turkey: LOW-MEDIUM

- Low port capacity; inland transportation mostly by truck.
- Coal's share of TPER was 21% in 1973, 27% in 1985.
- Low electricity production from coal in 1973 and 1978, moderately low in 1985; no nuclear power.

United Kingdom: HIGH

- Coal's share of TPER around 31-35%, 1973-1985, decreasing since 1973.
- Very high electricity production from coal; increasing use of nuclear power.
- Moderately low port capacity, adequate inland transportation network.

Table 3.1 Historical Coal Share of Total Energy and Electricity Production Statistics

Country	Percentage of Total Primary Energy Requirement Supplied by Coal			Electricity Production (TWh)								
				1973			1978			1985		
	1973	1978	1985	Coal	Oil	Nuclear	Coal	Oil	Nuclear	Coal	Oil	Nucle
Australia	38.0	34.7	40.4	48.2	1.7	-	60.7	5.3	-	88.9	4.7	-
Belgium	24.1	20.8	22.8	8.9	21.8	0.1	13.7	17.2	12.5	15.0	3.7	34.6
Canada	8.5	8.5	10.9	34.9	9.1	15.3	50.0	15.4	31.2	79.5	6.8	60.5
Finland	11.3	17.5	15.5	4.9	8.3	-	12.1	5.0	3.3	8.9	1.1	19.1
France	16.3	16.1	12.6	35.3	73.3	14.7	63.9	55.5	30.5	44.9	7.1	224.1
Germany	31.5	27.4	30.1	190.4	42.8	11.8	199.7	31.1	35.9	226.5	9.4	125.9
Greece	16.9	19.7	33.1	5.3	7.3	-	10.2	7.9	-	17.8	7.2	-
Italy	6.1	6.6	11.0	5.2	89.7	3.1	10.3	98.1	4.4	30.0	76.2	7.0
Japan	17.1	13.1	19.5	37.3	340.8	9.7	41.1	332.5	59.3	99.9	195.1	159.6
Netherlands	5.1	5.1	10.7	3.2	6.5	1.1	7.0	10.4	4.1	17.1	3.3	3.9
Portugal	6.2	4.2	6.0	0.4	1.9	-	0.2	3.3	-	1.0	6.6	-
Spain	16.2	13.5	26.1	14.3	25.1	6.5	20.9	28.8	7.6	55.5	8.1	2.0
Sweden	3.3	3.0	5.1	0.5	15.2	2.1	0.1	10.9	23.8	2.1	4.0	58.6
Turkey	21.0	20.2	27.0	4.2	5.5	-	5.6	6.7	-	15.0	7.1	-
U.K.	34.6	32.2	30.5	174.6	72.2	28.0	189.2	52.9	37.2	178.3	48.3	61.1

Source: IEA, Coal Information 1987.

Table 3.2 Capacity of Coal-Importing Ports

Capacity of Coal-Importing Ports (Million Metric Tons/yr)

	Throughput[1]	Current Effective Capacity[1]	Planned Additions to Capacity by 1990	Long-Term Proposed/ Planned Capacity Additions[2]
Australia	-	-	-	-
Belgium	29.3	57.9+*	-	-
Canada	17.0	28.1	-	-
Finland	4.5	23.1	-	-
France	23.5	62.4+*	-	2.5
FRG	8.8	19.3+	-	10.7
Greece	1.4	4.0+*	-	-
Italy	24.1	40.7+*	-	-
Japan	109.4	154.0+*	6.6	50.3
Netherlands	36.0	35.1	-	32.3
Portugal	0.9	*	5.0	-
Spain	10.8	32.3+*	-	7.4
Sweden	3.5	10.1	-	8.5
Turkey	2.0	2.9+*	-	-
U.K.	0.8	20.5	-	-

[1] Actual (as of 1985, 1986, or 1987)
[2] Projects which are uncertain or which will be completed after 1990

* Effective capacity data not available for all ports

Source: IEA, Coal Information 1987

Table 3.3 Coal Transportation Infrastructure

	Does a coal transportation infrastructure exist to transport coal to all major residential/commercial and industrial demand centers?
Australia	Yes. Adequate (rail). Expansion and upgrading continuing. Coal industry considers state-determined freight rates to be high.
Belgium	Yes. Adequate. Additional handling facilities may be required for substantial expansion of coal use.
Canada	Yes. Rail capacity being expanded.
Finland	No information available.
France	No information available.
FRG	Yes. Adequate (rail, IWT, roads)
Greece	Inadequate in both capacity and network spread.
Italy	Apparently adequate for coastal shipments. Inland transportation problematic.
Japan	Apparently adequate.
The Netherlands	Yes. Excellent inland transportation infrastructure (IWT, rail). Lack of space for new transportation developments could become a constraint in the future.
Portugal	Transportation infrastructure not yet in place.
Spain	Existing railways sufficient to handle domestic production. A few small lines might be added in the future.
Sweden	Yes. Apparently adequate for the near future.
Turkey	Mostly by truck. Expensive and inadequate for future development.
U.K.	Yes. Adequate (rail)

Source: IEA, Coal Prospects and Policies in IEA Countries: 1983 Review.

IEA, Coal Information 1987.

APPENDIX 4

RESIDENTIAL/COMMERCIAL ENERGY DEMAND
(Factor 4)

APPENDIX 4

Residential/Commercial Energy: Factor 4
COUNTRY SUMMARIES

Australia: MEDIUM-HIGH

- Moderately low total energy use (15 Mtce) in the residential/commercial sector, implying a moderately small retrofit market; moderate increase in res/com energy since 1978; healthy increase (2%/yr) by 2000 projected.
- Very small coal share of total residential/commercial energy use; decrease in coal share since 1978; negligible projected increase by 2000.
- High percentage of urban population in large cities; high percentage of urban dwellers in total population; second highest population growth between 1985 and 2000 of all countries considered.
- Res/comm sector uses almost 4 times as much oil as gas.

Belgium: LOW-MEDIUM

- Moderate level of current energy use in the residential/commercial sector (18 Mtce); decrease since 1978; no change projected by 2000.
- Coal share of total residential/commercial energy use is 8%, third highest of all countries considered; large decrease in coal share since 1973; decreasing trend to continue through 2000.
- High percentage of population in cities/towns of < 500,000 persons; very low population growth, 1980-2000.
- Some installed district heating and combined heat and power capacity; CHP capacity entirely coal-fired; government energy programs could favor district heat in buildings sector.
- Res/comm sector uses more than twice as much oil as gas.

Canada: MEDIUM-HIGH

- Moderately high total energy use in the residential/commercial sector (70 Mtce); increase of 1%/yr since 1973; increasing trend projected to continue through 2000. Total increase in energy use between 1985 and 2000 projected to be 16 Mtce. Therefore, potentially high retrofit and new combustor market.
- Very low coal share of current residential/commercial energy use; decrease in coal share since 1973; decreasing trend projected to continue through 2000.
- High percentage of population in large cities; third highest population growth of countries considered, 1980-2000.
- Canada uses more gas than oil in the res/comm sector.

Finland: LOW-MEDIUM

- Low total energy use in the residential/commercial sector (10 Mtce); roughly constant since 1973; slight decrease projected by 2000.
- Finland uses mostly oil (compared to gas) in the res/com sector.
- Current (1985) coal share of total residential/commercial energy use is 5%, up from 1% in 1978; coal share projected to increase to over 21% in 2000. However, due to fairly small energy requirements, the projected increase in coal use between 1985 and 2000 in Finland is only 1.5 Mtce.
- The population resides primarily in small cities and non-urban settings; only one city of more than 500,000; moderately low population growth, 1980-2000.
- Installed district heating and combined heat and power capacity; 38% of installed CHP capacity coal-fired; government policy promotes increased use of DH and CHP.

France: MEDIUM-HIGH

- Moderately high total energy use in the residential/commercial sector (70 Mtce), implying large retrofit market; 7% decrease since 1973; 2.5% decrease projected between 1985 and 2000.
- Coal share of total residential/commercial energy use was 5% in 1985, down from 11% in 1973, but it is expected to increase to 13.5% in 2000.
- Low percentage of urban population in large cities; high percentage of urban dwellers in total population; moderately high population growth, 1980-2000.
- France uses about twice as much oil as gas in the res/comm sector.

Federal Republic of Germany: MEDIUM-HIGH

- Highest total energy use in residential/commercial sector of all countries considered, so large retrofit market; slight increase since 1973 but decrease since 1978; decreasing trend projected to continue through 2000.
- Low coal share of total residential/commercial energy use; decrease in coal share since 1973; decreasing trend projected to continue.
- High percentage of population in small-medium cities; eleven cities of more than 500,000 persons; negative population growth, 1980-2000.
- Installed DH and CHP capacity; 15% of DH capacity and 52% of CHP capacity coal-fired; government is investing in development of coal-fired CHP systems.
- F.R.G. uses about twice as much oil gas in the res/comm sector.

Greece: LOW-MEDIUM

- Second lowest 1985 total residential/commercial energy use of all countries considered (8.5 Mtce); but increasing at 2%/yr since 1973; increasing trend projected to continue at 2.9%/yr through 2000.
- Very low current coal share of total residential/commercial energy use; coal share has been decreasing; decreasing trend projected to continue.
- No gas used in residential/commercial sector.
- High percentage of population in large cities; moderately low population growth, 1980-2000.

Italy: MEDIUM-HIGH

- Moderately high total residential/commercial energy use (52 Mtce); increasing at 1%/yr since 1973; increasing trend projected to continue at 1%/yr through 2000.
- Very low coal share of total residential/commercial energy use (<1%); stable since 1978; projected to increase by 2000.
- Moderately high percentage of population in large cities; low population growth, 1980-2000.
- About 40% more oil is used than gas in the res/comm sector in Italy.

Japan: MEDIUM-HIGH

- Second highest total residential/commercial energy use of all countries considered (93 Mtce); increasing at 2%/yr since 1973; increasing trend projected to continue at 2%/yr through 2000.
- Very low coal share of total residential/commercial energy use < 1%); decreasing since 1973; slight decrease projected by 2000.
- Moderately sized population in large cities; moderately high population growth, 1980-2000.
- Japan uses four times more oil than gas in the res/comm sector.

The Netherlands: LOW

- Moderate level of total residential/commercial energy use (30 Mtce); roughly stable since 1973; projected to decrease by 2000.
- Very low coal share of total residential/commercial energy use (0.3%); constant since 1978; slight increase projected by 2000.
- High percentage of population in small/medium-sized cities; moderately low population growth, 1980-2000.
- Installed DH and CHP capacity; government provides subsidies for DH projects. No coal use in DH or CHP.

- Indigenous gas supplies most of the res/comm energy.

Portugal: LOW

- Lowest 1985 total residential/commercial energy use of countries considered (3 Mtce); increasing since 1973; increasing trend projected to continue through 2000, but energy use still low (4 Mtce) in 2000.
- No historical or projected coal use in residential/commercial sector, 1973-2000.
- High ratio of oil use to gas use in residential/commercial sector.
- Fairly low percentage of urban dwellers in total population; only one city of more than 500,000; moderately high population growth, 1980-2000.

Spain: MEDIUM-HIGH

- Moderately low total residential/commercial energy use (16 Mtce); increasing at 3.6%/yr since 1973; increasing trend projected to continue (at 1%/yr) through 2000.
- Low coal share of total residential/commercial energy use (3%); increasing since 1978; increasing trend projected to continue through 2000 -- 8% of total res/comm energy use in 2000 to be supplied by coal.
- High oil/gas ratio.
- High percentage of urban dwellers in total population, about evenly split between large and small/medium sized cities. Moderately high population growth, 1980-2000.

Sweden: LOW-MEDIUM

- Moderately low total residential/commercial energy use (20 Mtce); decreasing since 1978; decreasing trend projected to continue through 2000.
- Very low coal share of total residential/commercial energy use (2%); no coal in 1978; small coal use increase projected by 2000.
- Very high oil/gas ratio (i.e., practically no gas used).
- High percentage of urban dwellers in total population, more in small-medium sized cities than large ones; no population growth projected.
- Installed DH and CHP capacity; small amount of coal-fired DH capacity; government encourages expansion of coal-based district heating systems.

Turkey: HIGH

- Moderately low current residential/commercial energy use (22 Mtce); increasing since 1973; projected almost to double by 2000.
- High 1985 coal share of total residential/commercial energy

use (13%); increasing since 1978; projected to double by 2000 (an increase in coal use of 9 Mtce between 1985 and 2000).

- Very high oil/gas ratio (almost no gas used).
- Only about half of population is urban; cities are primarily small/medium in size; projected population growth highest of all countries considered (~ 2% per year, 1980-2000).
- No installed DH or CHP capacity; R&D on DH and CHP is being carried out.

United Kingdom: LOW-MEDIUM

- High total residential/commercial energy use (63 Mtce); increasing since 1973; projected to remain roughly stable through 2000.
- High competition from indigenous natural gas.
- High 1985 coal share of total residential/commercial energy use (13%); decreasing since 1973; decreasing trend projected to continue through 2000.
- Highly urbanized; about half of cities are large (seventeen cities of more than 500,000 persons); low population growth, 1980-2000.
- Installed DH and CHP capacity (no info on fuels used); no government policy on DH or CHP.

Table 4.1 Historical and Projected Residential/Commercial Energy Use

Country	Total Res./Comm. Energy Use (Mtce)				Average Annual % Change		Absolute Change in Total Res. Comm. Energy, 1985-2000 (Mtce)	Current Ratio of Oil to Gas, 1985
	1973	1978	1985	2000	1973-1985	1985-2000		
Australia	13.1	13.1	14.9	20.1	+1.1	+2.0	+5.2	3.6
Belgium	18.4	19.7	17.6	17.6	-0.4	~0.0	0.0	2.3
Canada	62.0	69.4	70.3	86.7	+1.1	+1.4	+16.4	0.5
Finland	10.2	11.0	10.1	9.4	-0.1	-0.5	-0.7	42.0
France	77.2	77.3	71.8	70.0	-0.6	-0.1	-0.9	1.8
F.R.G.	112.4	119.4	115.7	103.3	+0.2	-0.8	-12.4	2.1
Greece	4.3	4.8	5.5	8.5	+2.0	+2.9	+3.0	no gas
Italy	45.7	49.4	51.8	59.3	+1.1	+0.9	+7.5	1.4
Japan	73.9	86.0	93.3	121.3	+2.0	+1.8	+28.0	4.3
The Netherlands	29.1	31.2	29.7	23.9	+0.2	-1.4	-5.8	0.1
Portugal	2.1	2.5	3.0	4.1	+3.1	+2.2	+1.1	15.0
Spain	10.4	12.8	15.9	18.6	+3.6	+1.1	+5.8	11.5
Sweden	20.4	20.7	19.8	17.3	-0.3	0.9	-2.5	72.0
Turkey	16.0	18.5	21.8	42.0	+2.6	+4.5	+20.2	53.0
United Kingdom	73.5	77.3	82.7	82.9	+1.0	-0.0	+0.2	0.3

Source: IEA, Coal Information 1987.

Table 4.2 Coal Share of Total Residential/Commercial Energy Use

Country	Nonmetallurgical Coal Use as a Percentage of Total Energy Use (%)				Projected Change In Coal Use, 1985-2000	
	1973	1978	1985	2000	Mtce	Avg Annual %
Australia	3.1	3.1	1.3	1.4	+0.1	+1.33
Belgium	16.8	7.6	8.0	4.0	-0.7	-4.33
Canada	1.0	0.3	0.3	0.1	-0.1	-0.45
Finland	2.0	0.9	5.0	21.3	+1.5	+9.75
France	11.0	7.4	5.4	13.5	+5.7	+6.21
FRG	13.2	6.3	5.7	3.5	-3.0	-4.03
Greece	2.3	0	1.8	1.1	<0.1	+3.8
Italy	1.5	0.6	0.6	2.3	+1.1	+11.14
Japan	3.3	0.9	0.6	0.5	<0.1	-0.15
The Netherlands	1.7	0.3	0.3	0.8	+0.1	+2.19
Portugal	~0	~0	~0	~0	<0.1	+17.09
Spain	3.8	2.3	3.1	8.0	+1.0	+7.04
Sweden	0.4	~0	2.0	2.8	+0.1	+2.19
Turkey	11.9	11.4	13.3	27.0	+8.5	+9.62
U.K.	25.4	16.6	13.1	8.6	-0.66	-2.73

Source: IEA, Coal Information 1987.

Table 4.3 Population and Urbanization

Country	Avg. Annual Growth of Population, 1980-2000 (%)	Percentage of Urban Population in Largest City, 1980	Percentage of Urban Population in Cities of >500,000 persons (1980)	Urban Population As Percentage of Total Population, 1984[a]	Number of Cities of >500,000 Persons, 1980
Australia	1.1	24	68	86	5
Belgium	0.1	14	24	89	2
Canada	0.9	18	62	75	9
Finland	0.3	27	27	60	1
France	0.5	23	34	81	6
FRG	-0.1	18	45	86	11
Greece	0.4	57	70	65	2
Italy	0.2	17	52	71	9
Japan	0.5	22	42	76	9
The Netherlands	0.4	9	24	76	3
Portugal	0.6	44	44	31	1
Spain	0.7	17	44	77	6
Sweden	0.0	15	35	86	3
Turkey	2.0	24	42	46	4
U.K.	0.1	20	55	92	17

[a] Estimates are based on different national definitions of what is "urban", and cross-country comparisons should be interpreted with caution.

Source: World Bank, World Development Report 1986.

Table 4.4A Status of District Heating (DH) and Combined Heat and Power (CHP)[a]

	Installed Capacity, 1981 MWth DH	CHP	% of Installed DH Capacity Supplied by Coal	% of Installed CHP Capacity Supplied by Coal	Do institutional factors (government policy goals) favor use of DH or CHP plants in the future?
Belgium	741	193	–	100	There is a program to look at rational use of energy in the domestic (buildings) sector - could favor district heating.
Finland	5163	3964	–	38	Yes. See comments, Table 4.4B
FRG	9950	21,050	15	52	Yes. See comments, Table 4.4B
The Netherlands	991	556	–	0	See comments, Table 4.4B.
Sweden	12,800	4,000	4[b]		Yes. See comments, Table 4.4B.
Turkey	None currently	None currently	–		R&D on district heating and CHP is being carried out. (The residential sector consumes 43% of total energy.)
UK	5707	93	–	–	See comments, Table 4.4b.

[a] Only countries for which information is available are shown. The other OECD countries are assumed to have little DH and CHP capacity

[b] includes wood

Source: IEA, District Heating and Combined Heat and Power Systems, A Technology Reveiw, 1983.

Table 4.4B Status of District Heating (DH) and Combined Heat and Power (CHP): Comments

Country	Comment
Finland	The government gives priority to combined electricity and heat supply in industrial and municipal back-pressure power plants when electric capacity is increased. A policy objective is to increase DH capacity by 600-700 MW a year during the 1980s. DH schemes are supported in areas where economically justified, and CHP is promoted by long-term loans.
FRG	The government places heavy emphasis on development of district heating based in particular on coal-fired, CHP, and waste heat recovery systems. The government has invested US $ 3 billion over 1981-85 and US $ 2.5 billion over 1986-1990 for, among other things, construction of new or extension of existing coal-fired CHP systems, conversion of oil or gas-fired CHP systems to coal, and conversion of existing coal condensing plant to combined production.
The Netherlands	Government provides subsidies for DH projects based on total energy saved over the life of the project with risk-bearing loans of up to 15-20% of total capital expenditure. However, social housing policy is a constraint: government financing does not allow for use of capital-intensive systems like district heating. Also, there is a trend toward more insulation and less energy use.
Sweden	The government has introduced measures to encourage development of district heating systems and believes that the expansion of district heating in the next decade should be based primarily on coal.
UK	The government has not formulated a policy on DH or CHP but has commissioned some studies. The National Coal Board operates a number of coal-fired heating-only DH schemes. There is some concern about eventually switching to combined production because of the relatively high price of UK coal.

Source: IEA, District Heating and Combined Heat and Power Systems, A Technology Review, 1983.

APPENDIX 5

INDUSTRIAL ENERGY DEMAND
(Factor 5)

APPENDIX 5

Industrial Energy Use: Factor 5
COUNTRY SUMMARIES

Australia: MEDIUM-HIGH

- Moderate level of total industrial energy use (27 Mtce), increasing since 1973; moderately high projected growth, 1985-2000 (13 Mtce).
- Moderate coal share of total industrial energy use (13%), lower coal share in 1985 than 1973, but higher than 1978; slight decrease in coal share projected by 2000.
- Large decrease in coal share in non-metallic minerals and food/tobacco since 1970 (possible reconversion).
- Equal amounts of oil and gas used in industry.

Belgium: LOW

- Low total industrial energy use (15 Mtce), decreasing since 1973, low projected growth (1.4 Mtce increase), 1985-2000.
- Moderate coal share of total industrial energy use (7%), stable since 1973, small projected increase in coal share (to 10% by 2000), but absolute increase in amount of additional coal used will be small.
- Moderately low coal share of energy use across most selected industry categories; high 1985 coal share (42%) of total energy use in non-metallic minerals (cement) industry--could be close to maximum cement industry coal use.
- Somewhat more oil than gas used in industry.

Canada: MEDIUM-HIGH

- High total industrial energy use (84 Mtce), increasing since 1973; high projected growth (34 Mtce to be added between 1985 and 2000).
- Current low coal share of total industrial energy use (3%), decreasing from 5% in 1973; small projected increase in coal share (to 6% in 2000).
- Moderately low 1985 coal share of energy use across most selected industry categories; moderately high 1985 coal share (32%) of total energy use in non-metallic minerals industry, up from 17% in 1970; however, elimination of coal in transport-equipment and food/tobacco industries between 1970 and 1985 (possible reconversion).
- Equal amount of oil and gas used in industry.

Finland: LOW

- Low total industrial energy use (13 Mtce), increasing since 1978; moderate projected growth (an increase of 5 Mtce between 1985 and 2000).

- Moderate current coal share of total industrial energy use (8%), roughly stable since 1973; insignificant projected increase in coal share.
- Low coal share of energy use across selected industry categories.
- Finland uses 8 times more oil than gas in the industrial sector.*

France: **MEDIUM-HIGH**

- Moderately high level of industrial energy use (61 Mtce), decreasing since 1973; no projected growth, but high potential retrofit market.
- Moderate current coal share of total industrial energy use (8%), increasing since 1973; projected increase in coal share (to 12% by 2000).
- Moderate coal share of energy use in most selected industry categories; somewhat higher coal share in "other industry" category. Coal share in cement and chemicals declined between 1970 and 1985, but it grew in other industrial categories.
- Twice as much oil as gas used in industry.

Federal Republic of Germany: **MEDIUM-HIGH**

- High current industrial energy use (96 Mtce), decreasing slightly since 1973; no projected growth, but high potential retrofit market.
- Moderate current coal share of total industrial energy use (10%), increasing since 1973; projected to decrease by 2000.
- Coal share of energy use in all selected industry categories except non-metallic minerals decreased between 1970 and 1985.
- About twice as much oil as gas is used in industry.

Greece: **MEDIUM-HIGH**

- Low industrial energy use (6 Mtce), increasing since 1973; moderate projected increase by 2000 (3 Mtce).
- High coal share of total industrial energy use, increasing from 8% in 1973 to 28% in 1985; projected to remain stable.
- Increasing coal share in non-metallic minerals (from 20% in 1970 to 70% in 1985), chemicals, and transport-equipment/machinery industry categories.
- Non-coal energy use is primarily oil.

Italy: **MEDIUM-HIGH**

- Moderately high total industrial energy use (53 Mtce), decreasing since 1973, moderately low increase projected by 2000 (a 7 Mtce increase).
- Current coal share of total industrial energy use is about

5%, up from 1.5% in 1973; projected to remain stable.

- Coal share of energy use in most industry categories declined somewhat between 1970 and 1985, but there is a moderately high 1985 coal share in non-metallic minerals industry (21%), an increase from 3% in 1970, could be potential to increase even further.
- Almost twice as much oil as gas is used in industry.

Japan: HIGH

- Highest industrial energy use of all countries considered (143 Mtce); decrease since 1973; high projected growth (59 Mtce) over 1985-2000.
- Moderate coal share of total industrial energy use (8%), increasing from 1.5% in 1973, projected to increase to 16% by 2000.
- Low coal share in the chemicals industry, but high 1985 coal share (62%) in non-metallic minerals industry.
- Much higher use of oil than gas.

The Netherlands: LOW

- Moderate total industrial energy use (28 Mtce); slight decrease since 1973; very low projected growth.
- Low coal share of total industrial energy use (1%), stable since 1973, projected to remain stable.
- Low coal share across selected industry categories.
- More gas than oil used in industry.

Portugal: LOW-MEDIUM

- Fairly low current industrial energy use (6 Mtce), increasing from 4 Mtce in 1973; projected to almost double by 2000 (a 5 Mtce increase between 1985 and 2000).
- Moderately low coal share of total industrial energy use (6%), increasing from 3% in 1978, projected to increase to 12% by 2000. However absolute amount of coal consumption will remain fairly small.
- Low coal share (19%) in the non-metallic-minerals (cement) industry, indicating a potentially large coal-conversion market there.
- No gas (only oil) is used in Portuguese industry.

Spain: MEDIUM-HIGH

- Moderate total industrial energy use (28 Mtce), small decrease since 1978, moderately high projected growth (16 Mtce increase between 1985 and 2000).
- Moderately low coal share of total industrial energy use (6%), up from 2% in 1978; increase to 12% projected by 2000.
- A decline in the coal share in the chemicals industry from 16% in 1970 to 3% in 1985 (potential reconversion); large

increase in the coal share of "other industry" energy use between 1970 and 1985.
- 10 times more oil than gas is used in industry.

Sweden: LOW

- Fairly moderate industrial energy use (18 Mtce), decrease since 1973, low projected growth.
- Low coal share of total industrial energy use (4%), increasing slightly since 1973, projected to increase slightly by 2000 (to 5%).
- Low coal share across most selected industry categories; high 1985 coal share (41%) of total energy use in non-metallic minerals industry (may have reached maximum).
- Mostly oil used in industry.

Turkey: HIGH

- Low industrial energy use (11 Mtce), increasing since 1973, projected to grow by 27 Mtce over 1985-2000.
- Moderately high coal share of total industrial energy use (18%); coal share has decreased slightly from 1973 share; projected to decrease slightly by 2000 (still remaining high relative to other countries considered).
- High coal share of total energy use in three of the selected industry categories: transport equipment and machinery, food and tobacco, and "other industry". Decreasing coal share between 1970 and 1985 in the chemicals industry (possible reconversion).
- Only oil (no gas) used in industry.

United Kingdom: MEDIUM-HIGH

- Moderately high industrial energy use (57 Mtce), decreasing since 1973, moderate projected growth by 2000 (8 Mtce increase). Therefore moderately high retrofit and moderate new-combustor markets.
- Moderate coal share of total industrial energy use, increasing since 1978, projected to increase to 15% by 2000.
- Declining coal share of total energy use between 1970 and 1985 in all industry categories (potential reconversion).
- About equal amounts of oil and gas used in industry.

Table 5.1 Industrial Sector Energy Use, 1973-2000

INDUSTRIAL SECTOR ENERGY USE, 1973 - 2000

	TOTAL INDUSTRIAL ENERGY USE* (Mtce)				Change in total industrial energy use, 1985-2000 (Mtce)	COAL SHARE OF TOTAL (%)				RATIO Oil/Gas (1985)
	1973	1978	1985	2000**		1973	1978	1985	2000*	
Australia	21.7	24.8	27.1	40.5[a]	+13.4	16.1	10.0	12.9	10.6	1.0
Belgium	20.8	19.4	14.8	16.2[b]	+ 1.4	7.2	8.2	7.4	9.8	1.5
Canada	64.1	77.8	83.6	117.6[b]	+34.0	4.8	2.6	2.6	5.9	0.9
Finland	12.6	11.5	13.1	18.5[b]	+ 5.4	7.9	5.2	7.6	8.1	7.6
France	73.4	70.8	61.3	60.6	- 0.7	5.5	3.3	7.9	12.0	1.8
FRG	101.1	96.9	95.9	95.7[b]	- 0.2	5.6	6.5	9.9	6.5	1.7
Greece	4.8	5.7	6.1	9.0[b]	+ 2.9	8.3	7.0	27.8	27.7	20.0
Italy	66.8	61.0	53.2	60.2[b]	+ 7.0	1.5	1.8	4.8	4.9	1.7
Japan	177.7	162.0	142.7	202.0[b]	+59.3	1.5	1.8	7.7	16.1	17.0
The Netherlands	29.8	31.7	27.8	29.1	+ 1.3	1.3	0.9	1.4	1.3	0.8
Portugal	3.8	4.9	6.4	11.5	+ 5.1	2.6	2.0	6.2	12.1	no gas
Spain	26.5	30.7	28.1	44.3[b]	+16.2	7.9	2.2	8.5	16.2	9.9
Sweden	21.5	19.2	17.7	21.4	+ 3.7	2.3	2.6	3.9	5.1	57.0
Turkey	5.7	9.8	11.3	38.0	+26.7	21.0	17.3	17.7	16.8	no gas
UK	89.1	75.9	57.8	66.2	+ 8.4	11.3	7.1	9.1	14.6	1.2

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* Excluding coal use in iron and steel industry

** Projected.

[a] Based on last year of available data for iron & steel consumption (1985).

[b] Based on last year of available data for iron & steel consumption (1985).

Source: IEA, Coal Information 1987.

Table 5.2 Energy Use in Selected Industries, 1970

	Coal Use (Mtoe)					Total Energy Use (Mtoe)				
	Non-Metallic Minerals	Chemicals	Transport Equipment & Machinery	Food, Beverage, & Tobacco	Other Industry*	Non-Metallic Minerals	Chemicals	Transport Equipment & Machinery	Food, Beverage, & Tobacco	Other Industry*
Australia	0.68	–	–	0.14	1.74	0.81	1.06	–	0.14	10.33
Belgium	–	0.13	–	–	0.70	0.43	3.90	0.08	0.09	4.75
Canada	0.25	–	0.10	0.05	2.49	1.45	3.96	0.33	0.33	34.70
Finland	–	0.02	–	–	0.74	0.22	0.70	0.16	0.38	5.16
France	0.73	1.35	–	–	1.83	2.16	10.10	1.13	2.14	26.08
FRG	1.46	2.57	1.00	0.67	1.36	7.73	16.07	6.00	3.04	13.31
Greece	0.01	0.00	–	–	0.00	0.05	0.45	–	0.01	1.43
Italy	0.28	0.38	0.25	0.06	0.04	6.32	15.34	3.36	2.02	5.90
Japan	–	–	–	–	3.15	7.89	30.00	–	2.00	33.97
The Netherlands	0.01	0.23	–	–	0.21	0.87	6.73	–	1.35	3.00
Portugal	–	–	–	–	0.18	0.42	0.41	–	0.15	1.43
Spain	–	0.38	–	–	1.20	0.28	2.42	0.01	0.16	9.10
Sweden	–	0.04	–	–	0.38	1.03	1.73	0.08	0.63	7.06
Turkey	–	0.21	–	–	0.23	–	0.09	–	–	4.72
UK	3.46	2.43	0.36	1.32	3.93	6.85	14.23	5.27	4.32	16.75

* Excluding iron and steel

Source: IEA, *Energy Balances of OECD Countries 1971-1981*.

Table 5.3 Energy Use in Selected Industries, 1985

	Coal Use (Mtoe)					Total Energy Use (Mtoe)				
	Non-Metallic Minerals	Chemicals	Transport Equipment & Machinery	Food Beverage & Tobacco	Other Industry*	Non-Metallic Minerals	Chemicals	Transport Equipment & Machinery	Food, Beverage, & Tobacco	Other Industry*
Australia	0.58	0.10	0.01	0.35	1.44	3.05	3.36	0.59	2.83	8.13
Belgium	0.50	0.05	0.01	0.12	0.08	1.30	4.42	0.52	0.88	36.16
Canada	0.90	0.17	-	-	0.91	1.58	13.30	0.66	0.88	35.08
Finland	0.50	0.05	-	0.03	0.08	0.80	1.63	0.34	0.59	4.05
France	1.23	0.04	0.14	0.26	0.96	3.70	16.38	3.59	3.50	9.47
FRG	2.00	2.05	0.42	0.30	1.07	5.98	24.58	5.83	3.05	10.06
Greece	0.99	0.16	0.01	0.01	0.14	1.28	0.46	0.05	0.29	2.08
Italy	1.35	0.14	0.05	0.03	0.05	7.40	12.50	3.31	1.87	5.53
Japan	4.06	0.82	-	-	2.03	7.05	30.72	3.37	3.06	38.17
Netherlands	0.10	0.33	0.01	0.03	0.09	0.84	13.96	0.79	1.55	3.14
Portugal	0.19	0.02	-	-	0.09	1.07	1.23	0.08	0.43	1.26
Spain	1.29	0.20	0.06	0.02	1.3	3.51	6.52	0.98	1.54	3.65
Sweden	0.24	0.06	0.02	0.03	0.17	0.59	1.45	0.91	0.53	7.27
Turkey	-	0.11	0.08	0.22	1.01	0.29	0.90	0.07	0.42	4.83
U.K.	1.30	0.38	0.23	0.23	1.68	3.65	12.04	5.09	3.35	9.75

* Excluding iron and steel

Source: IEA, Energy Balances of OECD Countries, 1970-1985.

Table 5.4 Coal Share of Total Energy Use in Selected Industries, 1970 and 1985 (%)

	Non-Metallic Minerals		Chemicals		Transport Equipment and Machinery		Food and Tobacco		Other Industry	
	1970	1985	1970	1985	1970	1985	1970	1985	1970	1985
Australia	84.0	28.3	0.0	5.5	-	1.7	100.0	8.8	16.9	18.0
Belgium	0.0	41.7	3.3	1.4	0.0	1.9	0.0	13.6	14.7	0.2
Canada	17.2	31.6	0.0	1.3	30.3	-	18.2	0.0	10.1	2.6
Finland	0.0	0.6	1.3	3.1	0.0	-	0.0	5.1	14.4	1.6
France	33.8	32.3	13.3	8.1	0.0	3.9	0.0	7.4	7.2	10.1
FRG	18.9	33.4	16.0	11.6	21.7	7.2	18.4	8.2	10.2	9.9
Greece	20.0	69.5	17.8	34.8	-	20.0	0.0	3.4	5.6	6.7
Italy	3.4	20.9	2.5	1.1	7.7	1.6	2.0	1.1	0.7	.9
Japan	0.0	61.9	0.0	3.7	-	-	0.0	-	9.4	5.3
The Netherlands	1.1	11.9	3.4	2.6	-	1.3	0.0	1.9	6.9	0.0
Portugal	0.0	17.8	0.0	1.6	-	-	0.0	-	12.6	7.1
Spain	0.0	36.8	15.7	3.1	0.0	6.1	0.0	1.3	13.2	35.6
Sweden	0.0	40.7	2.3	4.1	0.0	2.2	0.0	5.7	5.0	2.3
Turkey	-	-	42.9	12.2	-	28.6	-	52.4	4.9	20.9
U.K.	50.5	32.9	17.1	3.0	6.8	4.5	30.6	6.9	23.5	17.2

Source: Tables IV-2 and IV-3.

Table 5.5 Chief Industries in OECD Countries

Australia	Mining, manufacturing and transportation.
Belgium	Machinery, iron and steel, coal, textiles, chemicals, glass.
Canada	Motor vehicles and parts, fish and forest products, petroleum and natural gas, telecommunications, processed and unprocessed minerals.
Finland	Metal and steel, forest products, foodstuffs, textiles, clothing.
France	Steel, machinery, textiles and clothing, chemicals, food processing, aircraft, electronics.
FRG	Iron and steel, coal, chemicals, electrical products, ships, vehicles.
Greece	Processed food, textiles, metals, chemicals, electrical equipment, cement, glass, transport equipment, petroleum products, construction, electrical power.
Italy	Automobiles, machinery, chemicals, textiles, shoes.
Japan	Machinery and equipment, metals and metal products, textiles, automobiles, chemicals, electrical and electronic equipment.
The Netherlands	Petroleum refining, steel, metal products, electronics, bulk chemicals, natural gas.
Portugal	Textiles, footwear, wood and pulp, paper, cork, metal-working, ore processing, chemicals, fish canning, wine.
Spain	Processed foods, textiles, footwear, petrochemicals, steel, automobiles, consumer goods, ships.
Sweden	Machinery.
Turkey	Textiles, processed foods, iron and steel, cement, leather goods.
U.K.	Steel, heavy engineering and metal manufacturing, textiles, motor vehicles and aircraft, construction, electronics, chemicals.

Source: AID, Countries of the World Yearbook, 1988.

APPENDIX 6

TRADE RELATIONS
(Factor 6)

APPENDIX 6

Trade Relations: Factor 6
COUNTRY SUMMARIES

Australia: MEDIUM-HIGH

- Trade deficit with U.S.
- 28% of imports from U.S.
- Boilers imported from U.S.
- Current account deficit.

Belgium: LOW-MEDIUM

- Trade balance with U.S. is roughly zero.
- 5% of imports from U.S.
- Boilers imported from U.S. and exported to U.S.
- Current account surplus.
- Strong U.S. security/defense partner; significant U.S. presence.

Canada: HIGH

- Trade deficit with U.S.
- 79% of imports from U.S.
- Energy R&D agreements with U.S.
- U.S. and Canada engaged in trade negotiations; governments seeking to reduce or eliminate various tariff and non-tariff barriers to trade.
- Current account deficit.

Finland: LOW

- Small trade deficit with U.S.
- Only 5% of imports from U.S.
- USSR is major trading partner
- Current account deficit.

France: LOW-MEDIUM

- Small trade deficit with U.S.
- 7% of imports from U.S.
- U.S. is France's most important investor.
- Current account surplus.

Federal Republic of Germany: MEDIUM-HIGH

- Trade surplus with U.S.
- 6% of imports from U.S.
- U.S. dollar depreciating relative to D.M.
- Current account surplus.

- Strong U.S. security/defense partner; large U.S. presence in country (NATO).

Greece: LOW-MEDIUM

- Small trade deficit with U.S.
- 7% of imports from U.S.
- 51% of steam coal imports came from U.S. in 1986; 94% in 1982.
- Full repatriation of investments made after July 1986.
- Current account deficit.
- Recent member of EEC.

Italy: MEDIUM-HIGH

- Trade deficit with U.S.
- 11% of imports from U.S.
- 41% of Italy's steam coal imports came from U.S. in 1985.
- U.S. more competitive than Italy's other trading partners in large technology equipment, where Italians recognize superior U.S. standards.
- Current account surplus.
- M.O.U. with U.S. for cooperation in coal-related R&D.

Japan: MEDIUM-HIGH

- Trade surplus with U.S.
- 23% of imports from U.S.
- Small amount of coal imported from U.S.
- Yen appreciating against U.S. dollar.
- Bilateral and multilateral agreements with U.S.
- Current account surplus.

The Netherlands: MEDIUM-HIGH

- Trade deficit with U.S.
- 14% of imports from U.S.
- Coal imported from U.S. (30% of steam coal imports came from U.S. in 1985; 54% in 1982).
- Open trading environment.
- Current account surplus.

Portugal: LOW-MEDIUM

- Trade with U.S. in equilibrium.
- 8% of imports from U.S.
- Coal is second largest U.S. import; 63% of steam coal imports in 1986 were from the U.S..
- Turning more and more to Europe for trade partners.
- Current account surplus.
- U.S. AID-assisted country.

Spain: MEDIUM-HIGH

- Small trade surplus with U.S.
- 8% of imports from U.S.
- Some coal imported from U.S., but Australia and S. Africa have taken over the Spanish coal market.
- Government committed to developing high technology by promoting application of new technologies to existing industries.
- Current account surplus.

Sweden: LOW-MEDIUM

- Trade surplus with U.S.
- 7% of imports from U.S.
- Coal and coke imported from U.S., but U.S. steam coal imports have been virtually replaced by imports from Australia, Poland, and the U.S.S.R.
- Current account surplus.

Turkey: MEDIUM-HIGH

- Trade deficit with U.S.
- 11% of imports from U.S.
- Coal is second largest U.S. import; U.S. was sole steam coal supplier in 1986.
- Government encourages importation of foreign technology
- U.S. A.I.D.-assisted country.
- Current account deficit.

United Kingdom: MEDIUM-HIGH

- Trade surplus with U.S.
- 11% of imports from U.S.; fifth largest purchaser of U.S. goods (including power generating equipment).
- 26% of coal imports from the U.S. in 1986.
- Coal research agreements with U.S.
- Current account deficit.
- Major U.S. security/defense partner (NATO).

Table 6.1 Economic Indicators of Trade

Country	Balance Current Account	Balance Trade Account	Main U.S. Exports to	Main U.S. Imports from	$U.S. Export to	$U.S. Import from	US Trade Balance with	U.S. Share of Exports from(1)	U.S. Share of Imports to(1)	Comments
Australia	-8,100	-2,400	1.aircraft parts (852) 4. boilers, engines (283)	1. Beef&Sheep meat (683) 2. aluminum and ammonium (488) 3. returned U.S. products (223)	5,800	3,400	+2,400	15	20	The exchange rates have remained within a narrow band, but both U.S. & Australian currencies have further depreciated against the yen, D.M.
Belgium	3,310	-335	1. grain 2. combustion products 6. boilers & mechanical equip	1. Film 2. Diamonds 4. Boilers & mechanical equip	3,672	3,670	+.002	5.3	5.4	American products are 41% less expensive in 1987 than in February 1985, but competitors market aggressively and U.S. is perceived as not willing to adapt their products to European requirements.
Canada	-6,312	7,474	1. Auto & parts (20.8) 3. industrial machinery (4.3)	1. Auto & parts 2. lumber	49,610	37,239	+12,371	70	79	The bank of Canada may implement policies to avoid large swings in the US/Canada exchange rates that could affect trade. The Canadian dollar reached a three year high in April 1987.
Finland	-827	935	1. office machinery & (339) 2. chemicals (90)	1. Forest products 2. Skins, furs 3. Cheese 4. Alcoholic beverages	878	733	+145	4.8	5.4	The present weaker dollar should open up new opportunities for U.S. exports esp. test equipment and industrial process controls. USSR is a major trading partner.
France	5,000	84	1. Analytical Scientific instrumentation 2. 32% of total market computers	1. food products 2. chemicals 3. aerospace & rail technology 4. autos	9,469	8,806	+663	7.5	7.4	"U.S. exports to France increased 18% between 1985 and 1986, due to the decline in the value of the U.S. dollar.
FRG	36,900	50,300	1. machinery (1,238) 2. chemicals (1,134) 3. electronic (898)	1. Autos (4,956) 2. machinery (2,272) 3. chemicals (1,307)	10,218	21,173	-10,955	18.3	6.4	The U.S. dollar has been depreciating at the same time the DM has been appreciating, hence a double effect. The German coal industry has been hard hit by the broadening gap between international & domestic coal prices.
Greece	-1,704	-5,387	1. Crude materials 2. machinery & transport equip 5. coal & coke	1. manufactured goods 2. petrol products 3. beverages & tobacco	28	10	18	3.2	7.1	The drachma devalued against all currencies by 15% in 1985. The drachma depreciated by only 1.3% against the dollar in 1986. Full repatriation on investments made after July 1986.
Italy	4,782	-2,496	1. mechanical products (1,756) 2. chemicals (704) 3. energy products (651)	1. mechanical (2,457) 2. Textile & apparel (2,220) 3. metals (1,361)	10,465	5,683	+4,782	5.6	10.7	Current acct surplus due to cheaper lira prices for oil and other imports invoiced in dollars. Italy's import elasticity of demand is higher relative to other industrialised countries due to strong dependence on imported energy.
Japan	85,845	82,837	1. Foodstuff (5,329) 2. chemicals (3,563) 7. coal (774)	1. cars (25,989) 2. office machinery (5,747) 6. power generators (1,486)	25,935	77,335	-51,400	38.3	23.6	Trade surplus (Japan's) with the U.S. is $51.4 billion. The yen is a strong while at the same time the value of the dollar to yen is at a low since WWII. Major issue is Japan's trade surplus. Japan may make some efforts to reduce the trade imbalance with the U.S.

Table 6.1 Economic Indicators of Trade (Cont.)

Country	Balance Current Account[a]	Balance Trade Account	Main U.S. Exports to	Main U.S. Imports from	$U.S. Export to	$U.S. Import from	US Trade Balance with	U.S. Share of Exports from(%)	U.S. Share of Imports to(%)	Comments
Netherlands	3,600	3,900	1. machinery (993) 2. Animal feed (210) 7. coal (142)	1. Petrol products (119) 2. beer (157) 3. chemicals (290) 4. Transport equip (664)	4,400	2,800	+1,600	7.3	13.9	Dutch economy is more exposed to external shocks due to its high reliance on trade. Its trading position stems partly from its strategic location as a transportation center for Europe and partly from the openness of its trading environment.
Portugal	1,350	830	1. grain 2. coal 3. computer parts	1. molds for plastic 1. footwear 3. cork 4. wine	600	600	0	6.7	8.2	Even though the dollar is in a favorable position, Portugal is turning to the EC for trade, which it joined in 1986. The Portuguese government uses exchange rate policy to fight inflation. Coal remains the leading non-agricultural import from the U.S.
Spain	5,000	-5,559	1. soybean 2. seedcorn 3. coal	1. footwear 2. auto parts 3. cement 4. steel 5. olives	2,615	2,956	-341	9.2	8.1	FRG has supplanted US as #1 source of imports. France is its largest export market.
Sweden	1,300	4,800	1. machinery, appliances (1,044) 2. motor vehicles (312) 6. coal & coke (66)	1. cars 2. trucks 3. machinery	2,570	4,180	-1,610	10.1	7.1	The 25% drop of the krona against the dollar should make U.S. exports more competitive in Sweden.
Turkey	-1,528	-3,081[b]	1. Civil engineering & contracting services 2. coal 3. aircraft 4. scrap metal	1. Tobacco 2. refined petrol products 3. fruit & nuts 4. pig iron	1,177	549	+628	7.4	10.6	Turkey has formally applied to join the EC. In April 1987 the second meeting of the U.S.-Turkish Business Council took place in Washington, DC to discuss trade and investments.
U.K.	-1,750	-16,750	1. office machine 2. electrical 3. scientific equipment 4. power generating machinery	1. petrol & petrol products 2. auto/auto parts 3. jet engines 4. aircraft & parts	11,418	16,032	-4,614	14.1	11.3	The U.K. is the 5th largest purchaser of U.S. goods. The pound is the strengthening at the same time the dollar is weakening which augurs well for U.S. exporters 40% of all U.S. investment in Europe goe into the U.K.

[a] Values presented are for 1986. All data are in millions of U.S. dollars (1986 value).
[b] Turkey is the only country that includes gold bullion imports in the trade-balance figure.

Table 6.2 U.S. Investment in OECD Countries

Country	U.S. Investment $[a]	Comments
Australia	10,000 - 1984	There are 730 companies with subsidiaries, branches, etc. Another 300 firms have licensing agreements. The GOA is encouraging inward investment through liberalization of its investment review procedures.
Belgium	Information Not Available	Over 900 U.S. companies have operations here, nearly 400 of which are regional headquarters. Tighter environmental controls will be carried out on emissions from heating installations do to EEC directives.
Canada	48,840	The United States is Canada's principal supplier of foreign capital, accounting for 80% of all foreign direct investment. US/Canada gov'ts seek to reduce or eliminate a broad range of barriers to trade in current negotiations.
Finland	280 - 1981	U.S. investment remains at a modest level. Only a few U.S. sales and manufacturing subsidiaries are in operation. No intrinsic change in the structure of Fin/US trade is seen in the future.
France	7,835	Over 600 American firms are represented in France, which totals 1/3 of all foreign investment in France. U.S. investment in France has been dropping over the last four years.
FRG	18,620 - 1984	American direct investments in Germany have been in all the usual forms - branch offices, subsidiaries and joint ventures. In most cases, management has remained in German hands. Germany's central location, liberal attitude toward foreign investment, and predominant position in Europe are highly attractive.
Greece	2,800	86 U.S. regional marketing offices are based in Athens under Greek Law 2687. There are 5 U.S. bank branches located in Greece. U.S. investment in Greece represents 32% of all foreign investments. Investors will enjoy the right to full repatriation of profits earned on all investment of foreign capital made after July 25, 1986.
Italy	5,600	U.S. has been the leading foreign investor in Italy for over a decade with 6,500 U.S. firms represented. Some 40% of U.S. investments are wholly U.S. owned. The U.S. is most competitive with Italy's other trading partners in high tech equip. in which Italian's recognize superior American standards.
Japan	3,000	Japan is the 8th largest recipient of U.S. investments, which accounted for more than 1/2 of major direct investment in Japan in 1986. GOJ appears to take a positive attitude toward foreign investment and its promotion.
Netherlands	7,000	The U.S. is the Netherlands largest source of foreign direct investment with holdings of over $7 billion. There are over 1,000 U.S. firms with offices there. The Dutch market is relatively free of serious barriers to U.S. exports. In parallel with the trading climate, the investment environment is remarkable free of major impediments.
Portugal	575	U.S. investment in 1986 was $13 million, which was $13 million, which was only 8% of total 1986 foreign investment inflows into Portugal. Some incentives for investment established in 1986, are to encourage efficient energy use.
Spain	2,600	New tax investment laws have been passed. They are more liberal and simplified. The FRG stands with 1/3 of all foreign investment with U.S. as a distant 2nd. The GOS is actively promoting the creation of new industries and the application of new technologies to existing industries.
Sweden	520	There are about 170 subsidiaries and affiliates of U.S. companies operating in Sweden. Over 1/2 are sales and distribution-firms. Sweden does not offer special tax or other inducements to attract foreign capital.
Turkey	36.5	Twenty-two American firms maintain operations in Turkey. A number are engaged in the petroleum foreign industry. U.S. investment represents 11.8% of total investment in Turkey. In order to stimulate the Turkish economy, the GOT actively encourages the importation of foreign capital and technology.
U.K.	38,000	80% of the approx. 2,000 U.S. branches, subsidiaries are 100% U.S. owned. They tend to be in the export-oriented industries. The U.S. generally welcomes foreign investment.

[a] All values are in millions of dollars (1986). All investment is total cumulative value. Values are given at end 1985 - beginning 1986 levels unless noted. Due to the depreciation of the dollar in 1987, the 1987 figures would be lower than those presented for 1986 for all countries.

"Data Source: Foreign Economic Trends (FET) Overseas Business Reports (OBR), from Dept. of Commerce"

Table 6.3 Historical Coal Imports from the United States to OECD Countries

Country	Steam Coal Imports from the United States (10^3 metric tons) 1978	1980	1982	1984	1986 (est.)	U.S. imports as a % of total steam imports 1978	1982	1986	Comments
Australia	–	–	–	–	–	–	–	–	
Belgium	–	1436	1360	613	671	0.0	22.4	15.0	U.K. competes with Germany and S. Africa in Belgium.
Canada	8796	9305	11141	11762	9672	100.0	100.0	100.0	U.S. is sole importer of both coking and steam coal to Canada.
Finland	–	533	676	1	396	0.0	14.5	7.3	Imports from USSR and Poland have been increasing in Finland.
France	36	2680	4563	666	1683	0.2	30.7	14.9	Total coal imports to France have been declining between 1982 and 1986; greater share has gone to Australia in that period.
FRG	33	1218	2486	1163	807	0.5	23.6	8.2	Imports to FRG from Poland and S. Africa increased between 1982 and 1986.
Greece	–	–	476	613	930	0.0	93.9	31.1	Main U.S. competitors in Greece are Australia and S. Africa.
Italy	–	1327	4970	2870	6446	0.0	51.7	48.6	Imports have increased from S. Africa between 1982 and 1986.
Japan	–	368	1642	460	553	0.0	11.4	2.3	U.S. exports to Japan are small compared to those from Australia, Canada, Russia, China, S. Africa.
The Netherlands	14	1083	3850	2133	2749	0.6	33.7	35.3	Imports to the Netherlands from Australia and S. Africa increased between 1982 and 1986.
Portugal	–	–	29	–	900	0.0	62.2	62.7	The rest of the imports to Portugal come primarily from S. Africa and the U.K.
Spain	–	727	2730	487	342	0.0	77.1	6.3	Coal from Australia and S. Africa has supplanted U.S. coal in Spain.
Sweden	–	54	641	337	197	0.0	50.7	7.2	Increased imports to Sweden from Australia, Poland and USSR, 1982-1986.
Turkey	–	–	–	–	133	–	–	100.0	
U.K.	1	2167	395	408	1126	0.0	27.0	26.2	Between 1984 and 1986, U.S. and Australian imports to the U.K. have risen, whereas S. African and Polish imports have declined.

Source: IEA, Coal Information 1987.

Table 6.4 Energy Research Agreements Between OECD Countries and the United States

Australia:	A DOE/FE - Australia bilateral agreement in the area of coal dating from June 1978 to June 1983, is now inactive. No funds have been budgeted or spent. There are no products resulting from this agreement. The purpose was for the exchange of information concerning coal conversion extraction processing, mining and magnetohydrodynamics. The U.S. DOE/FE is a participant in three multilateral agreements of which Australia is also a participant.
Belgium:	At the present time the U.S. DOE/FE does not have a bilateral agreement with Belgium.
Canada:	U.S. DOE/FE currently has four active bilateral agreements with Canada in the following areas: resource characterization of tar sands, steam-flooding with additives in a tar sand deposit, dissemination of information (oil), and monitoring frontal movements in thermal recovery. The U.S. and Canada also participate in six multilateral agreements.
FRG:	U.S. DOE/FE has just completed a bilateral agreement that involved the design, construction, testing, and evaluation of a plant converting approximately 100 barrels of methanol per day to gasoline/olefins in a fluidized bed reactor. There currently is participation in two multilateral agreements.
Finland:	DOE/FE has a general cooperative bilateral agreement in energy research and development with Finland that has been extended until November 6, 1990, but there are no active annexes at this time.
France:	At this time DOE/FE does not have any bilateral or multilateral agreements with France.
Greece:	At this time DOE/FE does not have any bilateral treaties with Greece, nor is Greece a participant in any multilateral treaties which include DOE/FE.
Italy:	At the present time DOE/FE has one memorandum of understanding for cooperation in fossil fuels research and development, which activities include coal water mixtures, structure and reactivity of coal, combustion studies, enhanced oil recovery, plus eleven other topics. An implementing agreement for a program for direct coal liquefaction was signed on December 5, 1985 for a five-year period. The US DOE/FE and Italy also participate in two multilateral agreements.
Japan:	The DOE/FE and Japan currently have one general bilateral agreement with the Ministry of International Trade Industry and one memorandum of understanding with the Agency of Industrial Science and Technology. The US DOE/FE and Japan participate in four multilateral agreements.
Netherlands:	There are no bilateral agreements between the DOE/FE and the Netherlands, but there is participation in three multilateral agreements.
Portugal:	Portugal and the DOE/FE do not participate in any energy related agreements at this time.
Spain:	The US DOE/FE and Spain have completed work on two annexes of an implementing agreement between the DOE/FE and the Institute De Catalisis Y Petroleoquimica. A third annex was signed in December 1985 for a three year period. The Institute Geologico Minero Espana and the DOE/FE have completed three annexes under a general agreement and have signed a fourth in December 1985 for a three-year period. The US DOE/FE and Spain also participate in two multilateral agreements.
Sweden:	The US DOE/FE and Sweden do not have any bilateral energy agreements at this time, but do participate in three multilateral agreements.
Turkey:	At the present time the U.S. DOE/FE and Turkey do not participate in any bilateral or multilateral energy related agreements.
UK:	The US/DOE/FE and the UK/DOE have one memorandum of understanding for collaboration in energy research signed October 1984. The US DOE/FE and the NCB (National Coal Board), CEGB (Central Electricity Generating Board) have a memorandum of agreement

APPENDIX 7

Lack of Domestic Competition: Factor 7
COUNTRY SUMMARIES

Australia: LOW-MEDIUM

- Moderately high budget for coal R&D in 1983; high coal R&D share of total energy R&D budget; coal R&D budget increasing.
- Low level of private coal R&D.
- Moderate level of advanced coal technology (ACT) manufacturing activity.

Belgium: LOW-MEDIUM

- Moderately low budget for coal R&D in 1986; moderately high coal R&D share of total energy R&D budget; stable coal R&D budget.
- Moderate level of private coal R&D.
- Low level of ACT manufacturing, but collaborative ACT R&D with Germany and the Netherlands (hence, imports more likely from those countries).

Canada: MEDIUM-HIGH

- Moderately high budget for coal R&D in 1986; moderately low coal share of total energy R&D budget; decreasing trend in coal R&D budget.
- Moderate level of private coal R&D.
- Some ACT manufacturing.
- Strong ACT demand, interest in U.S. suppliers.

Finland: LOW-MEDIUM

- Moderate level of ACT manufacturing.
- Strong domestic industry in various ACTs; emphasis on heat combustion.

France: MEDIUM-HIGH

- Manufacturing of conventional boilers has occurred in the past, but declining coal production appears to have limited development of new technologies. Hence, little experience with ACT.

- Interest in small combustors.

Federal Republic of Germany: LOW

- High budget for coal R&D in 1986; moderately high coal R&D

share of energy budget; stable coal R&D budget.
- High level of private coal R&D.
- High level of ACT manufacturing.
- Major ACT exporting country.

Greece: HIGH

- Low budget for coal R&D in 1986; moderately high coal share of energy budget; stable coal R&D budget.
- Low level of private coal R&D.
- Low level of ACT manufacturing.

Italy: HIGH

- Low budget for coal R&D; very low coal share of energy R&D budget; stable coal R&D budget.
- Low level of private coal R&D.
- Low level of ACT manufacturing.
- Interest in coal is very recent; ACT demonstrations planned.

Japan: LOW

- Budget for coal R&D is highest of all countries considered (U.S. $202.6 million in 1986); coal share of energy R&D budget is fairly low; coal R&D budget is stable.
- High level of private coal R&D.
- High level of ACT manufacturing.
- Leader in domestic R&D and commercial activity.

The Netherlands: LOW-MEDIUM

- Moderately high budget for coal R&D; high coal share of energy R&D budget; increasing trend in coal R&D budget.
- High level of private coal R&D.
- Domestic ACT manufacturing.
- Waste disposal problems; need ACT that minimizes waste.

Portugal: HIGH

- Very low budget for coal R&D; very low coal share in energy R&D budget; coal R&D budget stable.
- Low level of ACT manufacturing.

Spain: MEDIUM-HIGH

- Moderately low coal R&D budget; moderately high coal share of energy budget; decreasing trend in coal R&D budget.
- Moderate level of private coal R&D.
- Some domestic ACT manufacturing.
- ACTs for treatment of high sulfur coal important.

Sweden: LOW-MEDIUM

- Low coal R&D budget; moderately high coal R&D share of energy R&D budget; coal R&D budget stable.
- High level of private coal R&D.
- High level of ACT manufacturing.
- Leaders in novel FGD, AFB and NO_x control.
- U.S. role possible.

Turkey: HIGH

- Low budget for coal R&D; high coal R&D share of total energy R&D budget; stable coal R&D budget.
- Low level of private coal R&D.
- Low level of ACT manufacturing.
- Need ACT for clean lignite combustion.

United Kingdom: LOW-MEDIUM

- Low government budget for coal R&D; very low coal R&D share of total energy R&D budget; coal R&D budget stable.
- High level of private coal R&D.
- High level of ACT manufacturing.

~~110~~ 109

Table 7.1 Domestic Competition

Country	1986 Coal R&D Budget (10^6 U.S. \$)	Recent Trend in Coal R&D Budget	Percent of Energy R&D Budget that is Coal	1986 Coal R&D Budget per GDP ($x10^6$)	Relative Private Coal R&D Involvement	Domestic ACT Manuf. Activity	Favored Technologies	Notes
Australia	23.0 (1983)	Up	28 (1983)	N.A.	Low	Med	AFB CWM Gasif. Liquef.	Competition only for ACT that will burn Australian coals.
Belgium	10.0	Same	14	0.13	Med	Low	AFB Gasif.	Domestic R&D seems adequate to meet limited needs. No large domestic ACT industry; but collaborative R&D being conducted with Germany and the Netherlands.
Canada	21.0	Down	6	0.06	Med	Med	AFB Gasif. Sorb. inj. Lo-Nox B. AFGD	Declining R&D budget, but quite strong ACT demand. Interest in U.S. suppliers.
Finland	N.A.	N.A.	N.A	N.A.	N.A.	Med	Spray dry. Sob. inj. AFB Gasif.	Strong domestic industry in varied ACT. Emphasis on heat combustion, not big in U.S.
France	N.A.	N.A.	N.A.	N.A.	N.A.	Low	Sorb. Inj.	No great experience with ACT due to declining domestic coal industry. Interest in small combustors.
FRG	106.9	Same	19	1.17	High	High	AFGD SRC AFB Gasif. Liquef.	Very strong domestic ACT industry. Major exporting country. Not much opportunity to penetrate market
Greece	2.6	Same	17	0.08	Low	Low	N/A	No significant experience with ACT. Minimal R&D budget. Good prospects.
Italy	4.4	Same	1	0.02	Low	Low	AFGD SCR AFB Gasif. Liquef.	Little interest in coal R&D until just recently. Several ACT demos planned. No domestic industry.

Table 7.1 Domestic Competition (cont.)

Japan	202.6	Same	9	0.16	High	High	APGD SCR AFB Gasif.	Leaders in domestic R&D and commercial activity. Very hard for U.S. to compete.
Netherlands	43.3	Up	27	0.35	High	Med	APGD AFB Gasif. SCR Lo-Nox B.	Intensive Federal R&D Program. Waste disposal problems. Significant domestic industry.
Portugal	0.2	Same	3	N.A.	N.A.	Low	None	No significant initiatives in ACT development or commercial usage.
Spain	12.2	Down	17	0.07	Med	Med	APGD prep. AFB PFB	ACT for pre-Coal treatment of high-S coal are important. FBC is under development. Potential for small units.
Sweden	9.1	Same	11	0.09	High	High	Spray dry. APGD Gasif. SCR, SNR	Strong leadership, especially in novel FGD, AFB, and NO_x control. Some industry but U.S. role possible.
Turkey	0.5	Same	21	0.01	Low	Low	Coal Prep. AFB	Minimal R&D and experience. Need ACT for clean lignite combustion.
U.K.	4.4	Same	1	0.01	High	High	AFB PFB Gasif. Lo-NO_x B.	Moderate control Tech. favored (not much FGD, no SCR). Currently R&D is low but manufacturers exist.

N.A. = Not available.

N/A = Not applicable.

Sources: Coal Advisor Board (IEA). Environmental Strategies for Coal Use.

IEA, Clean Coal Technologies: Programmes and Issues.

IEA, Energy Policies and Programmes of IEA Countries.

J. Vernon (IEA), Personal communication.

APPENDIX 8

ENVIRONMENTAL PRESSURE
(Factor 8)

APPENDIX 8

Environmental Pressure: Factor 8
COUNTRY SUMMARIES

Australia: LOW

- No strong environmental pressure for ACT.
- No acid rain or long-range transport problems.
- Existing regs. permit combustion of domestic coals without controls.
- No solid waste disposal problems.

Belgium: LOW-MEDIUM

- Required emission reductions to be achieved by increased nuclear power, fuel switching, and energy conservation.
- Low-sulfur coal and emissions bubbling preferred for smaller units.
- No FGD systems planned (and no new, large coal-fired plants).
- Concern that EEC proposal would inhibit oil-to-coal conversions.

Canada: MEDIUM-HIGH

- Strong environmental concerns over acid rain damage.
- Major reduction in SO_2 emissions planned by 1994, some from smelters.
- Other reductions to be achieved by increased hydro and nuclear, increased electricity imports, use of low-sulfur coal, and 15-20 FGD retrofits.
- Interest in ACT at R&D and pilot plant scale (FBC, slagging combustor, IGCC). Opportunities for commercial ACT to reduce emissions.

Finland: MEDIUM-HIGH

- New regs. in 1987 require 70-80% reduction in SO_2 emissions from new plants >50 MWt: proposals for S-in-fuel limits on smaller units.
- Preferred controls for large plants are spray dryers.
- Environmentally benign use of coal (and peat) is a policy objective in Finland, since the nuclear option has been halted. AFB; low-energy gas from peat, wood waste, and coal; and combined heat and power for district heating are all in use or planned.

France: MEDIUM-HIGH

- Emission reduction target of 65% by 1995 expected to be easily met at low cost by continued emphasis on nuclear power generation, and switching away from high-S fuel oil.

- No federal regs., but S-in-fuel regs. for major urban areas (Paris, Marseilles, Lyon, etc.).
- Sulfur emissions in smaller units expected to increase as French coal industry seeks to replace coal lost to nuclear in the power generation sector.
- No large-scale air pollution problems in France, but opportunities for ACT to burn coal in urban areas could be significant.

Federal Republic of Germany: HIGH

- Detailed and stringent emission regs. for new and existing, large and small (>1 MWt) combustors.
- Strong environmental pressure for emission reductions as a result of forest damage due to acid rain. Some expansion of nuclear power, but most of the reduction will come from FGD retrofits.
- Low-S coal may be adequate for small units, but there is strong pressure for AFB or other ACT. NO_x reductions called for also, which favors certain ACT.
- Tax relief for new, clean technologies could further spur development and commercial installations.
- Waste disposal regs. force the use of regenerable or salable-waste control systems.

Greece: MEDIUM-HIGH

- No existing federal regs., but EEC Directive would apply in the future. Local regs. are strictest in the Athens area (0.7% S in fuel oil).
- Environmental concern over damage to historical structures has led to new urban planning measures in Athens, where most of industrial and commercial activity resides.
- Potential role for ACT, especially for burning low-quality domestic lignite. Scope limited, however.

Italy: HIGH

- No federal emission regs. below 100 MWt, but coal use limited to 1% S in fuel. Local air pollution more important than acid rain or long-range transport.
- Emphasis at large plants on multi-fuel capability with FGD systems. Two AFB units planned by 1991.
- ACT for smaller plants would help achieve the 30% reduction goal and ameliorate waste disposal problems.

Japan: HIGH

- A strong SO_2 and NO_x control program is in place at both federal and local levels.

- FGD and $DeNO_x$ technologies are utilized on major plants, mostly with waste minimization techniques.
- There is strong domestic R&D into many kinds of ACT, especially coal liquids and gases and FBC.

Netherlands: HIGH

- A strong control program is in place, similar to the FRG; limits for smaller plants can be met with low-sulfur coal. High environmental awareness.
- There is domestic interest in ACT to improve energy efficiency while providing additional environmental protection. AFB and IGCC are already under development in support of an active coal policy.
- Waste disposal is a major issue due to shortage of land.

Portugal: LOW-MEDIUM

- No emission limits in place that would require FGD or equivalent ACT; some S-in-fuel restrictions.
- No strong environmental awareness. Not a member of the 30% club. Policy is to wait for EEC Directive.
- No firm plans for FGD at few large coal plants that are in place.
- Although S in coal is high and ACT could improve environment, there seems to be little pressure at present to absorb higher costs of ACT.
- For government projects (such as some district-heating projects), funding could come from an international organization, such as the World Bank, in which case environmental issues would have to be addressed.

Spain: MEDIUM-HIGH

- Emission limits are set very high to accommodate local high-sulfur (4-7%) coals with some blending and washing. FGD systems are favored.
- Spain is not a member of the 30% club and has resisted tighter emission standards.
- Spain's policy is to achieve emission reductions in the longer term by developing and utilizing new technologies that can burn indigenous coals cleanly and efficiently.
- Emerging interest in ACT, especially PFB and AFB. Potential opportunities for U.S. technology to assist in Spain's domestic policy goals.

Sweden: HIGH

- Strong domestic air pollution and high environmental awareness.
- FGD systems, particularly spray dryers, are favored for large units.

- Strong interest in AFB and PFB and sorbent injection systems for smaller units. NO_x control is a big issue in Sweden with potential for U.S. combined SO_2/NO_x technologies to fill a niche.

Turkey: LOW-MEDIUM

- Environmental awareness just emerging; air pollution regs. passed in 1986 are not thought to be very stringent.
- Turkey is looking for ways to burn domestic lignites cleanly, but resources devoted to R&D are small and commercial interest is low.
- Despite some concern over pollution levels, the environmental push for cleaner technology must be considered relatively small at present.

U.K.: MEDIUM-HIGH

- If proposed regs. are adopted, new industrial coal-fired boilers would require 30-90% SO_2 reduction.
- Role exists for ACT having lower removal efficiencies.
- Domestic R&D interest in AFB, PFB, and IGCC; low-NO_x burners are preferred for NO_x control.
- With extensive history of coal use in residential/commercial and industrial sectors, coupled with pressure from other European countries, opportunities for ACT as expansions or conversions will exist.

Table 8.1 Environmental Pressure for Advanced Coal Technology (ACT)

Country	SO$_2$ Regs*	NO$_x$ Regs*	Notes
Australia	No federal emission regs (local impacts of concern). 1.76 lb/10^6 Btu in N. Territory	No regs for units <150 MM Btu/hr.	No real prospects for ACT from an environmental perspective. No acid rain problems. Low-sulfur coals can be burned uncontrolled under existing regs.
Belgium	1.76 lb (new) and 2.8 lb (existing) for 50-100 MWt units. Proposed 30% reduction by 1995.	0.65 lb (new) and 0.32 lbs (new after 1995 for 50-100 MWt units. "BAT" (Existing).	Required reductions to be achieved with increased nuclear and fuel switching. Proposed limits achievable through use of low-S coal. No FGDs planned. No plans for large-scale coal increase.
Canada	Federal guideline is 0.6 lb/10^6 Btu. Provincial regs.: 50% reduction by 1994.	Federal guideline is 0.6 lb/10^6 Btu.	Some opportunities from an environmental perspective. Some reduction achievable through increased hydro/nuclear, low-S coals. FGD or ACT is planned at 15-20 units. R&D interest in ACT.
Finland	0.5 lb/10^6 for 50-150 MWt (New). 1.2% S coal elsewhere. 30% reduction by 1993.	No Regs.	Existing regs. will require 70-80% SO$_2$ reduction on larger coal plants. Proposal for mandatory use of low-S coal on other plants. FGDs being installed. ACT could compete.
France	No federal emission regs. Some cities limit S in coal (0.7 - 1.4% S). 65% reduction by 1995.	Target of 20-30% reduction by 2000. No Regs.	Increased nuclear, fuel substitution, and S-in-fuel limits expected to achieve emissions goals. ACT could perhaps compete with low-S coal in protected urban areas (Paris, Marseilles, Lyon, etc.).
FRG	Detailed regs in place: 1.76 lb. (new) 1.76 lb. (existing) 0.32 lb (FBC) for 1-50 MWt units.	1-50 MWt: 0.4 lb/10^6 Btu (new/existing) 1-20 MWt: 0.4 lb (FBC) 20-50 MWt: 0.24 lb	Detailed emission regs. for both new and existing plants (large and small). Low-S coal adequate for small installations, but considerable pressure for FBC (or other ACT). Tax relief for ACT.
Greece	No existing Federal regs. EEC directive would apply in future. Strict limits (0.7% S fuel oil) in Athens area.	No federal regs.	Absence of federal regs., need to reduce SO$_2$ emissions, strong environmental awareness (re: historical structures), and recent urban planning measures imply potentially large role for ACT.
Italy	No emission regs below 100 MWt. 1% S-in-fuel limit 30% reduction planned.	No federal regs below 100 MWt.	Extensive use of FGD planned at new, large plants. Two AFB units by 1991. Multi-fuel plants are in favor. Potential role for ACT on smaller units to help achieve 30% reduction.
Japan	Source-specific regs. S-in-Fuel limits of 0.5 - 1.2% S.	All small units limited to 0.58 lb/10^6 Btu.	Strong control program in place. Strict limits imposed at federal and local levels. Extensive commercial use and R&D into ACT. Novel FGD systems favored for large plants.
Netherlands	For 50-300 MWt units: 0.57 lb/10^6 (new) and 1.2% S (existing). 50% reduction by 2000.	For <300 MWt : 0.65 lb (New, pre-88) 0.40 lb (New, pre-88)	Limits for smaller, existing plants can be met by low-S coal. Interest in ACT to improve efficiency while providing additional environmental protection. AFB and IGCC under development.

Table 8.1 Environmental Pressure for
Advanced Coal Technology (ACT) (cont.)

Country	SO_2 Regs*	NO_x Regs*	Notes
Portugal	No federal regs. Not a member of 30% club.	No federal regs.	No emission limits in place that would require controls or ACT. Some S-in-fuel limits. No firm plans for FGD at few coal plants existing or planned. Little incentive for ACT at present.
Spain	Regs. for industrial boilers: 1.94 lb (hard coal). 4.8 lb (brown coal).	No federal regs.	Emission limits are very high to accommodate local high-S (4-7%) coal with some blending and washing. No FGD planned. In the longer term, major role possible for ACT that can utilize high-S coal.
Sweden	Federal guidelines: 0.46 - 0.78 lb/10^6 Btu for plants emitting <400 tons/yr. 65% reduction by 1995.	Proposed Guidelines: 0.46 - 0.92 lb/10^6 Btu for new and existing plants.	Strong control program and environmental awareness. Lime spray-dryers favored now, with AFB seen as having potential. R&D into sorbent injection for future small units. High potential for ACT.
Turkey	New regs. in 1986, but details not available.	Probably not covered in new regs.	More information needed. It is believed that new regs. are not very stringent. Environmental awareness has only recently begun.
U.K.	Proposed regs.: 1.1 lb/10^6 Btu and 30-90% reduction (new) for 30-100 MWt units	No regs. propos d for new plants over 30 MWt.	If proposed regs. adopted, new industrial boilers would require 30-40% SO^2 reduction. Role for ACT ACT having lower reduction efficiencies Domestic interest in AFB, PCB, and IGCC. Low-NO_x burner for NO_x control.

*In almost all countries, there are no statutory limits for smaller industrial combustors (e.g.,<50 MWt) or residential/commercial combustors. In such cases, control is exercised through the planning process, which is administered by the appropriate local authority. The requirements imposed may often be case-specific. Information on such requirements can only be obtained by detailed investigations. Nevertheless, it is believed that examination of the statutory requirements for the smallest class of non-utility combustors (which are included in the table) is a good indicator of likely regulations for smaller combustors.

Table 8.2 Solid Waste Issues in OECD Countries

SOLID WASTE DISPOSAL ISSUES IN OECD COUNTRIES

Australia	*No major concerns. Sufficient land available for disposal.*
Belgium	Regional responsibility, with emphasis on waste minimisation and regenerable control systems. No waste FGD producing systems allowed. Ash is largely re-used in cement manufacture. Land is limited, but no major concerns at present.
Canada	No national solid waste disposal policy; provincial governments issue permits for solid waste disposal. Characterisation studies of FGD waste, FBC waste, and disposal options are under way.
Finland	FGD waste is currently disposed of as landfill. Strong interest in reusable waste products from spray drying and sorbent injection. Sorbent injection limits the re-use of fly ash. Concrete and road bed materials are desired.
France	Waste disposal requirements are determined for individual facilities after public hearings. A general policy of limiting waste generation and encouraging recycling exists. Disposal is usually to land, sometimes in nearby coal mines.
Germany	Demonstration of waste minimisation is required as part of licencing procedure. This has forced the choice of either gypsum-producing FGD systems or regenerable systems. Market exists for sulfur products. Ash is often disposed of in worked-out coal mines.
Greece	Local requirements only. Land availability for disposal is becoming a serious problem.
Italy	Disposal of wastes to land is becoming a serious problem, leading to the selection of regenerable FGD systems or technologies with usable waste.
Japan	The 1970 Waste Management Law requires isolation of wastes from surface waters and groundwater. Land reclamation from the sea by waste filling is now strictly controlled. Severe shortage of land for disposal has resulted in a waste minimization policy that effectively forces the use of regenerable or similar systems.
Netherlands	Strong policy to limit waste generation is in effect. Utilities have set up a company, Vliegasunie, to market coal combustion by-products. Wastes are used for cement, asphalt, roadbed, and concrete production. May be a surplus of usable gypsum from regenerable FGDs by 2000.
Portugal	No national policy or regulation. Requirements established on a plant-by-plant basis as part of the licensing process.
Spain	No problems yet, because no FGD systems in place. Regenerable FGD systems are not attractive due to glut of sulfur products.
Sweden	Landfill is currently adequate and of low cost. Coal combustion waste is often dumped with household garbage. Environmental pressure exists for re use of wastes, but strict regulations control acceptable leaching rates from such applications.
Turkey	Awareness of environmental issues such as solid waste disposal is just beginning. One approach is to improve the quality of Turkish lignite prior to combustion. Disposal of wastes does not appear to be a major problem.
U.K.	No national policy for disposal of combustion wastes, but waste minimization is encouraged according to the EEC directive. Waste disposal was a major factor in the U.K. decision to install FGD systems with salable products. However, gypsum production may exceed market demand.

Sources for Tables 8.1 and 8.2

IEA, Environmental Strategies for Coal Use.

IEA, Coal Information, 1987.

IEA, Clean Coal Technology, Programmes and Issues.

OECD, Coal: Environmental Policies and Institutions.

J. Vernon (IEA), personal communication.

Mr. BOUCHER. The next two witnesses are Mr. Ben Yamagata from the Clean Coal Technology Coalition and Dr. Kurt Yeager from the Electric Power Research Institute.

Gentlemen, we'll be happy to hear from you.

Mr. Yamagata, we welcome you this morning, and we'll be happy to hear your statement at this time.

PANEL: PRIVATE SECTOR

STATEMENT OF BEN YAMAGATA, EXECUTIVE DIRECTOR, CLEAN COAL TECHNOLOGY COALITION, WASHINGTON, DC

Mr. YAMAGATA. Mr. Chairman, Members of the Subcommittee, on behalf of the Clean Coal Technology Coalition, I first want to express our appreciation for the opportunity to testify before this Subcommittee. We did so, you may recall, in September of 1986. You, Mr. Chairman, and other Members of the Science, Space, and Technology Committee have been strong and effective advocates of the Clean Coal Program, and I want to take this opportunity on behalf of the Coalition to thank you for these efforts.

The Clean Coal Technology Coalition was organized in the spring of 1985 for the specific purpose of encouraging the implementation of the Clean Coal Program and accelerating the development of promising clean coal technologies. With your permission, I would like to focus my oral comments upon the four principal issues that are discussed more fully in my written testimony.

First, the focus of the Clean Coal Technology Development Program should be to encourage all promising technologies, not only so-called retrofit or repowering technologies, but also technologies for new "greenfield" applications. Some in the Congress and others interested in this program believe that all funds should be directed toward retrofit technologies only. These are technologies which, if successful, would assist in achieving some near-term reductions on existing facilities.

While we support the accelerated development of retrofit technologies in order to provide additional options by which industry might cost-effectively reduce emissions, if ongoing scientific inquiry finally determines such additional reductions are needed, we also urge the Congress to continue support for technologies that can be applied to repowering new facilities. It is this set of technologies that is vitally important to our future ability to cost-effectively generate electricity or energy while, at the same time, effectively controlling emissions. Many of these technologies were initially authorized by this Committee, and research and development efforts undertaken by the Government and the private sector should be brought to fruition where these technologies can benefit the environment and your constituent ratepayers.

Some have objected to providing incentives to the deployment of clean coal technologies as well. Concerns over deployment may be the consequence of a lack of uniform agreement about what is meant by the term "deployment." In the utility industry, it is especially important that a technology not only be proven to be technically feasible but also that the technology be proven to be economically viable and operationally reliable.

Therefore, the Coalition believes that multiple, full-scale commercial deployment projects of the same or similar technology should be encouraged. That is what the Coalition means when we speak of a deployment program. Accomplishment of such a deployment program would assure hands-on experience with the technology and would bring down the costs of early commercial sized units.

In other words, a successfully-implemented deployment program of additional demonstrations could bring a technology to commercial readiness such that the risk of using the technology would be well within acceptable commercial limits. The amount of funding to be made available in the current solicitation suggests that these replications, at least of certain technologies under different and real-world operating conditions, could be initiated.

The second matter I'd like to address involves DOE administration of the Clean Coal Program. We are generally pleased with the final Program Opportunity Notice, or PON, which the Department issued on February 22. Many Coalition questions about program direction and requirements were addressed in the final PON, and we anticipate further Departmental clarification at the pre-proposal conference to be held in Washington in mid-March.

Also with respect to DOE administration, given the need to demonstrate a diversity of emerging technologies so as to provide a variety of cost-effective options, we would observe that the second solicitation represents an opportunity, if worthy projects are proposed, to select technologies that are not chosen under the first solicitation. We would agree with you, for example, Mr. Chairman, that there is an opportunity, again, if projects are acceptable, to select precombustion coal preparation or coal cleaning processes as well as advanced combustion FGD processes which were left out of the first round.

Third, I must reiterate the Coalition's position that acid rain control legislation and successful development of emerging clean coal technologies do not appear to be compatible. It is clear that stringent emission control legislation will siphon funds away from clean coal technology development because industry will naturally utilize options that are tried and true even if they may be more expensive and perhaps less effective. There is a strong temptation to argue that clean coal technologies will be commercially available for utilization before major emission reductions are required under current acid rain proposals. Unfortunately, that does not appear to be the case. The demonstration of new technologies, as this committee well knows, simply takes time.

Finally, the Coalition is on record in support of a multi-year Clean Coal Demonstration and Deployment Program. We support the President's request for additional funding, with the important caveat that the amount of funding, the time frame in which that funding is to be made available, and the direction and scope of future program opportunity notices are all important matters that must be carefully considered and questioned as issues about additional funding are answered.

For example, we believe that the Clean Coal Program, as I previously stated, should be focused on supporting technologies up to the stage of commercial readiness. Such a strategy is, I think, quite consistent with the President's program but might be more fully defined if Congress chooses to appropriate those additional amounts requested.

The United States has embarked upon an ambitious and important initiative in the clean coal area. If the program is successful, the environment will benefit, our national energy security will be strengthened, the use of U.S. coal resources will be better assured, and, importantly, consumers' electric and energy bills might be kept to a minimum. This is an important program and deserves continued support.

I appreciate the opportunity on behalf of the Coalition to present this testimony, and, at the appropriate time, I'll be pleased to answer any questions you might have.

Thank you.

[The prepared statement of Mr. Yamagata follows:]

HEARINGS ON THE FISCAL YEAR 1989 BUDGET REQUEST
FOR THE DEPARTMENT OF ENERGY
FOSSIL ENERGY PROGRAM

BEFORE THE

HOUSE COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
U.S. HOUSE OF REPRESENTATIVES

WRITTEN STATEMENT OF
BEN YAMAGATA, EXECUTIVE DIRECTOR
CLEAN COAL TECHNOLOGY COALITION

MARCH 2, 1988

I. INTRODUCTION

This written statement is submitted by Ben Yamagata, Executive Director of the Clean Coal Technology Coalition.

The Coalition is an ad hoc group of electric utilities, equipment suppliers, coal companies, architect-engineering and construction firms, several state governments, universities, the National Coal Association, the Edison Electric Institute and the United Mine Workers of America. A membership list of the Coalition is attached to this testimony for the information of the Committee (see: Attachment A). The Clean Coal Technology Coalition (CCTC or Coalition) was organized in early 1985 for the specific purpose of encouraging the early demonstration and accelerated commercialization of clean coal technologies.

Our membership supported action by the Congress last year to appropriate $575 million for a second round of clean coal technology demonstrations. The CCTC also supports -- to the extent of our knowledge of them -- the recommendations of the President's Task Force on Regulatory Relief. From our understanding, the Task Force has recommended changes to existing federal regulations that will further encourage utility use of clean coal technologies.

The industry/government partnership currently embodied in the clean coal program is an important initiative which can accelerate the commercialization of emerging technologies. Most importantly, success in this effort will allow for the use of our nation's plentiful coal resources in a cost-effective and environmentally acceptable manner.

II. SUBJECT MATTER ADDRESSED IN THIS TESTIMONY

We appreciate this opportunity to comment upon the current clean coal program and the President's request for additional appropriations. This written testimony addresses the following four areas:

1. The current focus of the clean coal program with regard to retrofit and repowering technologies and the demonstration and deployment of these technologies;

2. Department of Energy administration of the second phase ($575 million) of the clean coal technology program;

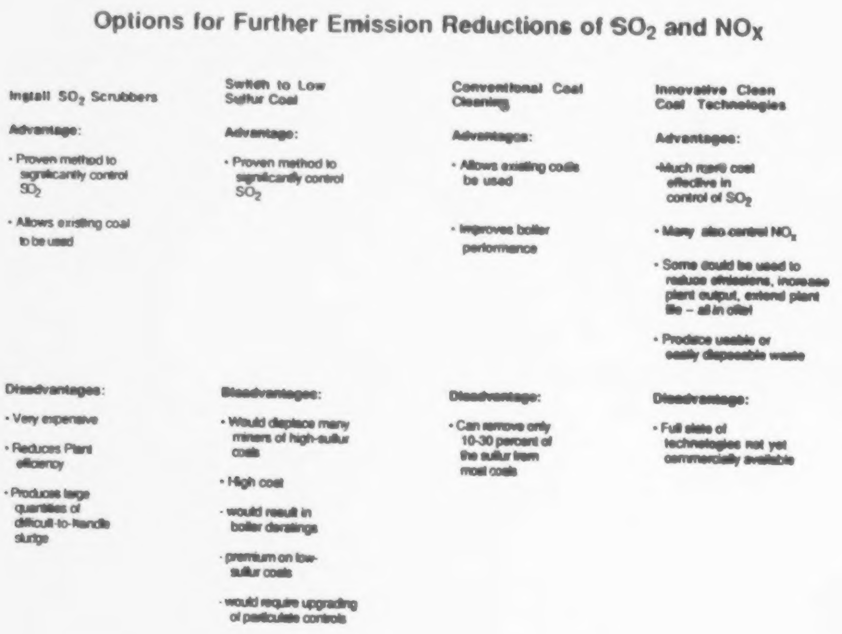
3. If current acid rain control legislation is enacted, further demonstration and commercialization of clean coal technologies becomes highly unlikely; and

4. The President's request for an additional appropriation of $1.775 billion to the clean coal program.

III. SCOPE AND FOCUS OF THE CURRENT CLEAN COAL PROGRAM

Some in the Congress and elsewhere have advocated that the financial incentives provided under the clean coal program be made available for retrofit technologies only. While we support retrofit technology development, financial incentives should also be available for repowering and new technologies. Further, retrofit technologies should be developed, demonstrated and brought to commercial readiness through a well-conceived deployment program. If ongoing scientific inquiry determines that additional emission reductions are necessary -- this information is being gathered and a final report will be issued by the National Acid Precipitation Assessment Program (NAPAP) at the end of 1990 -- then an aggressive clean coal program could assure that several cost-effective retrofit options are available for commercial use in a timely manner.

However, it would be particularly short-sighted to abandon support for those technologies that are capable of repowering existing facilities or providing more cost-effective and efficient emission control when applied to new powerplant or industrial settings. The Department of Energy has summarized the advantages to ratepayers and national energy security, as well as our environment, if these clean coal technologies are successfully developed and widely used. The DOE summaries are reproduced below for the information of the Committee.



Options for Further Emission Reductions of SO_2 and NO_X

Install SO_2 Scrubbers	Switch to Low Sulfur Coal	Conventional Coal Cleaning	Innovative Clean Coal Technologies
Advantage:	**Advantage:**	**Advantages:**	**Advantages:**
• Proven method to significantly control SO_2 • Allows existing coal to be used	• Proven method to significantly control SO_2	• Allows existing coals be used • Improves boiler performance	•Much more cost effective in control of SO_2 • Many also control NO_x • Some could be used to reduce emissions, increase plant output, extend plant life -- all in one • Produce usable or easily disposable waste
Disadvantages:	**Disadvantages:**	**Disadvantage:**	**Disadvantage:**
• Very expensive • Reduces Plant efficiency • Produces large quantities of difficult-to-handle sludge	• Would displace many miners of high-sulfur coals • High cost · would result in boiler deratings · premium on low-sulfur coals · would require upgrading of particulate controls	• Can remove only 10-30 percent of the sulfur from most coals	• Full slate of technologies not yet commercially available

U.S. Department of Energy

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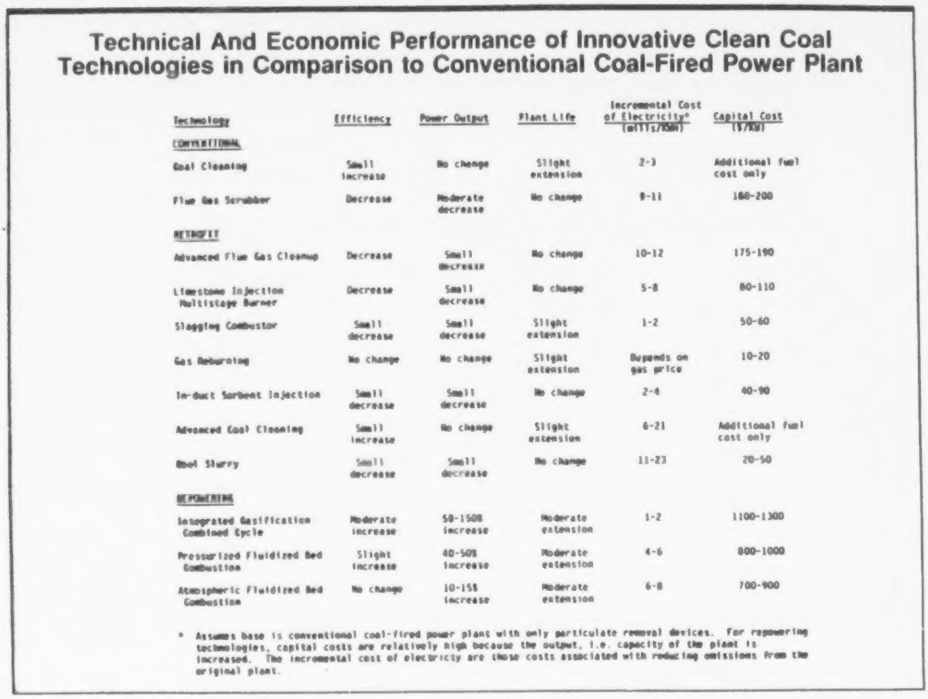


Technical And Economic Performance of Innovative Clean Coal Technologies in Comparison to Conventional Coal-Fired Power Plant

Technology	Efficiency	Power Output	Plant Life	Incremental Cost of Electricity* (mills/KWH)	Capital Cost ($/KW)
CONVENTIONAL					
Coal Cleaning	Small increase	No change	Slight extension	2-3	Additional fuel cost only
Flue Gas Scrubber	Decrease	Moderate decrease	No change	9-11	180-200
RETROFIT					
Advanced Flue Gas Cleanup	Decrease	Small decrease	No change	10-12	175-190
Limestone Injection Multistage Burner	Decrease	Small decrease	No change	5-8	80-110
Slagging Combustor	Small decrease	Small decrease	Slight extension	1-2	50-60
Gas Reburning	No change	No change	Slight extension	Depends on gas price	10-20
In-duct Sorbent Injection	Small decrease	Small decrease	No change	2-4	40-90
Advanced Coal Cleaning	Small increase	No change	Slight extension	6-21	Additional fuel cost only
Coal Slurry	Small decrease	Small decrease	No change	11-23	20-50
REPOWERING					
Integrated Gasification Combined Cycle	Moderate increase	50-150% increase	Moderate extension	1-2	1100-1300
Pressurized Fluidized Bed Combustion	Slight increase	40-50% increase	Moderate extension	4-6	800-1000
Atmospheric Fluidized Bed Combustion	No change	10-15% increase	Moderate extension	6-8	700-900

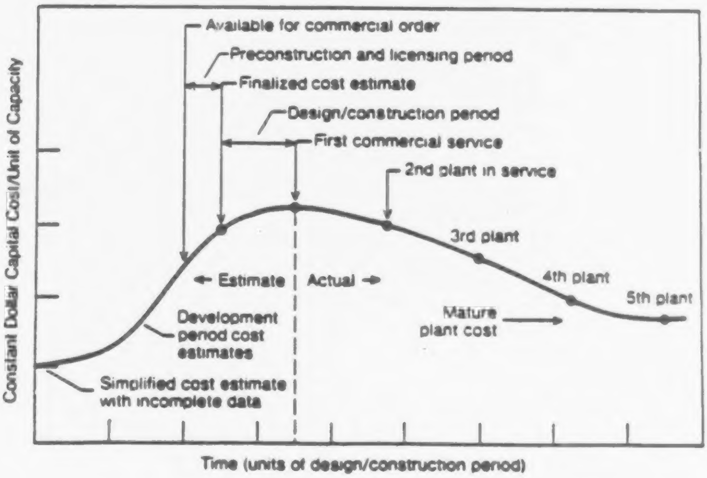
* Assumes base is conventional coal-fired power plant with only particulate removal devices. For repowering technologies, capital costs are relatively high because the output, i.e. capacity of the plant is increased. The incremental cost of electricty are those costs associated with reducing emissions from the original plant.

U.S. Department of Energy

A second question that has been raised in the context of increased funding for the clean coal technology development program is whether such funds should be utilized for the deployment of successfully-demonstrated technologies.

The CCTC supports a deployment program and would observe that considerable confusion has developed over the term "deployment". Perhaps a more accurate description of the Coalition's position is that we support additional demonstrations of a technology needed to bring that technology to commercial maturity or readiness. That stage of development (commercial readiness) ensures that the technology is ready to be used in widespread commercial application.

Multiple plant demonstrations also offer the benefit of providing "hands on" experience among potential users. It is this experience that is so critical to the pace of market penetration for a given technology. It is well accepted that the first commercial project using a new technology will cost more than that project which represents a subsequent mature technology. This is so in the utility industry especially where reliability of operation is paramount. Initial demonstrations may require that a facility be "over-engineered" or that there be redundancy to ensure reliability. These measures add to cost. Experience lessens those costs. This developmental process is depicted by the following chart:



Cost Learning Curve

Electric Power Research Institute

The objective of supporting multiple plant applications is to refine the technology so that its capital and operating costs can be reduced to levels necessary for commercial utilization. A deployment assistance program to provide grants of up to 50 percent of construction and operating costs would be established by legislation pending in the Senate (S.879, The Clean Coal Technology Deployment Act). President Reagan's proposed 5-year, $2.5 billion program would also provide assistance for an accelerated technology deployment program although further clarification of the President's program to verify the technology deployment objective would be helpful.

IV. DOE ADMINISTRATION OF THE CLEAN COAL PROGRAM

As this Committee knows, the DOE has recently issued a final program opportunity notice (PON) for clean coal technology project proposals. Generally, the Coalition is very encouraged by the contents and requirements of this PON which is in sharp contrast to our concerns about the first clean coal solicitation issued in 1985. The Department conducted numerous public meetings in 1987 and, it appears, the DOE has made significant efforts to accommodate the concerns and recommendations raised by the private sector at those meetings. Also, some requirements proposed in the draft PON and in need of clarification were indeed clarified or changed in the final document issued on February 22. We are hopeful that other questions about the PON will be answered when the Department conducts its pre-proposal conference on the PON later this month.

When the Coalition testified before this Committee last September, we stated our belief that the Department must seek to encourage the demonstration of several generic technologies which were proposed, but not chosen, under the first clean coal program. Where the program is intended to encourage the demonstration of as many promising options as possible, then several additional generic technology areas should be supported. These are: pre-combustion coal cleaning; and advanced post-combustion clean-up, including advanced flue gas desulfurization technologies and regenerable FGD technologies. Further, it would appear that sufficient funds are available under the new solicitation to support additional repowering technologies. The Department is encouraged to support these technology areas should acceptable projects be proposed.

Finally, to insure that a successful program is conducted we recommend that the Department continue vigorous efforts to keep the Congress fully and currently informed about the progress of the program and the projects already selected and those to be selected. Obviously, committee oversight hearings are but one method to provide information. It is our hope that the Congress and the administering department will continue both formal and informal dialogues so that all interested parties are kept fully informed about the program. The Coalition will certainly continue to do all possible to assure that Members of this Committee are apprised of industry perceptions about the program.

V. CLEAN COAL TECHNOLOGIES ARE NOT LIKELY TO BE DEPLOYED IF ACID RAIN LEGISLATION IS ENACTED

As we have testified in the past, it is the belief of the Coalition that passage of acid rain control legislation that mandates major, near-term reductions in SO2 and NOx emissions will stifle clean coal technology development. The capital requirements to comply with proposed acid rain control legislation would be immense and funds available for new technological development would be siphoned off to ensure compliance with the regulatory program. It is also possible that existing plants might be closed on the basis of economic considerations, thus bringing the reliability of today's electric energy supply into question and raising concerns over the electric industry's ability to construct new facilities for tomorrow's needs. Finally, a requirement for immediate SO2 reductions would require widespread use of expensive and troublesome flue gas scrubbing systems since other, more promising and cost-effective clean coal technologies are not yet commercially available. The end result of a regulatory program will be delay or abandonment of the development of clean coal technologies.

There is a strong temptation to argue that clean coal technologies will be commercially available for utilization before major emission reductions are required under current acid rain control proposals. Unfortunately, such is not the case.

The demonstration of new technologies simply takes time. Even if Congress provides additional funding for an aggressive deployment program of additional demonstrations designed to bring technologies to commercial readiness, the utility industry will be unable to commit, plan and begin incorporating these technologies before the turn of the century. Without the clean coal program, it will take even longer. It takes approximately three to five years to permit, engineer, design and build a commercial demonstration plant and two more years to conduct testing. To be available for widespread use in the late 1990's and at the turn of the century, a series of clean coal technology demonstrations must be initiated now.

VI. THE PRESIDENT'S REQUEST FOR ADDITIONAL FUNDING

The Coalition is on record in support of a major, multi-year demonstration program like that currently proposed by the President. While we support additional funding for clean coal technology development beyond that already appropriated, we are also aware of the need to proceed with caution and clarity of purpose.

If the Congress chooses to appropriate those additional amounts requested by the President for fiscal year 1990 and beyond, careful consideration needs to be given to the total level of funding, the period of time during which those funds would be made available, and the scope and direction of future DOE solicitations. We believe, for example, that the clean coal program should be focused on supporting technologies up to the stage of commercial readiness. Such a strategy, which is consistent with the President's program, would provide the country with a large array of options. If it is determined after on-going scientific inquiry that further emission reductions are necessary then technologies to meet that need will already be under development. Also, the government in partnership with the private sector could concurrently support the development of those promising clean coal technologies that might assist in meeting the demands for future electricity and energy through the use of coal in a cost-effective and environmentally-acceptable manner.

CONCLUSION

The United States has embarked upon an important initiative in the development of emerging clean coal technologies. Government financial support which is directed at technologies supported by the private sector can serve as an important stimulus to accelerated development of those technologies. If the program is successful, the environment will benefit, our national energy security will be strengthened, the use of U.S. coal resources will be assured and consumers' electric or energy bills will be kept to a minimum. The benefits are really enormous and the Committee is urged to continue its support for this important program.

CLEAN COAL TECHNOLOGY COALITION

MEMBERSHIP

February 26, 1988

A.T. Massey Coal Company, Inc.
Allied-Signal, Inc.
Allison Gas Turbine Division, General Motors Corporation
Amax Coal Company
American Electric Power Service Corporation
Arch Mineral Corporation
Babcock & Wilcox
Baltimore Gas & Electric Company
Bechtel Power Corporation
Bethlehem Steel Corporation
Carolina Power & Light Company
Centerior Energy
Central Illinois Public Service Company
Cincinnati Gas & Electric Company
Combustion Engineering, Inc.
Consolidation Coal Company
Costain Coal, Inc.
Cyprus Coal Company
Duke Power Company
Edison Electric Institute
Florida Power Corporation/Electric Fuels Corporation
Florida Power & Light Company
Fluor Corporation
General Electric Company
General Public Utilities, Inc.
GWF Power Systems Company, Inc.
Illinois Power Company
Indianapolis Power & Light
Industrial Fuels Corporation
Island Creek Corporation
Jersey Central Power & Light Company
M. W. Kellogg Company
Madison Gas and Electric Company
Marietta Coal Co.
Metropolitan Edison Company
MHD Development Corporation
National Coal Association
National Lime Association
Northern Indiana Public Service Co. (NIPSCO)
Ohio Edison
Ohio Mining and Reclamation Association
Oklahoma Gas & Electric Company
Orange and Rockland Utilities, Inc.
Peabody Holding Company, Inc.
Pennsylvania Electric Company
Pennsylvania Power & Light Company
Pittsburg & Midway Coal Mining Co.

Public Service Company of Indiana
Sargent & Lundy
South East Coal Company
Southern California Edison Company
Southern Company Services
Southern Illinois University at Carbondale
Stone & Webster Engineering Corporation
Texaco, Inc.
The Commonwealth of Kentucky
The State of Illinois
The State of Indiana
The State of Minnesota
The State of Ohio
The State of West Virginia
TransAlta Utilities Corporation
Union Electric Company
United Coal Company
United Mine Workers of America
School of Mines and Energy Development, University of Alabama
University of Southern Indiana
Virginia Power
West Virginia University
Wisconsin Power & Light Company

Mr. BOUCHER. Thank you, Mr. Yamagata.

Dr. Yeager, we'll be happy to hear from you.

STATEMENT OF DR. KURT E. YEAGER, VICE PRESIDENT AND DIRECTOR, COAL COMBUSTION SYSTEMS DIVISION, ELECTRIC POWER RESEARCH INSTITUTE, PALO ALTO, CA

Dr. YEAGER. Thank you, Mr. Chairman, Members of the Committee. I am Kurt Yeager, and I am Vice President of the Electric Power Research Institute and Director of its Coal Combustion Systems Division, and I also appreciate this invitation to again meet with you to discuss the issues of Innovative Clean Coal Technology and its implications for both improved energy productivity and environmental protection, and with your concurrence I will summarize from my full statement which I have submitted for the record.

Over the past two years, the initiatives of Congress to encourage a demonstration of Innovative Clean Coal Technology have offered welcome confirmation of the strategic importance that these technologies hold for electric power production and our Nation's productivity.

Our economic competitiveness in the global market depends on the continued availability of low-cost electricity from coal and environmental improvements which are sustainable only if they are part of an economically viable system. An intelligently planned and developed program in Innovative Clean Coal Technology can, in my judgment, provide this win-win solution for the Nation.

In order to achieve this solution, the electric utility industry and the Electric Power Research Institute have invested more than $1 billion in ushering Innovative Clean Coal Technology toward commercial maturity.

The current period provides a unique and essential opportunity to capitalize on this investment and to bring this next generation of coal-based power technologies to commercial readiness for the essential needs of the 1990's and beyond. I am encouraged that this objective is now within our grasp through the Innovative Clean Coal Technology Program which provides a level development playing field for new technology.

Simply stated, Innovative Clean Coal Technology is intended to reduce the policy conflict between coal use and environment. It has, over the past years, evolved into a family of precombustion, combustion, and post-combustion processes providing the diversity of coal users with the technical flexibility to resolve that conflict in both an environmentally-holistic manner and at the lowest possible cost. The benefits achievable include both decreased cost of energy production from coal, sustained environmental improvement, improved competitiveness for both U.S. coal and technology, and reduced reliance on imported energy.

I believe, though, that an understanding of the Innovative Clean Coal Technology breadth of technology suggests that they be usefully separated into two categories. First are the opportunities of technologies to provide more productive power generation alternatives for both existing and new plants. Generic examples include fluid bed combustion and coal gasification. The bottom line of these technologies is both to provide increased opportunity and cost reduction for increased coal use while sustaining the environmental improvements that have been initiated over the past 15 years.

The second dimension of clean coal technology is substantially different, and that is retrofittable emission control options. These do not aid and add to productivity, they simply reduce the productivity loss that would accrue to the imposition of controls on existing plants. They therefore provide insurance in the event that additional emission control requirements are necessary on existing plants, and I would underscore that an aggressive demonstration program is necessary for both categories and that the first category, in my judgment, is the strategically more important for the Nation.

The demonstration initiative recognizes the characteristic learning curve associated with all new technologies and the need to share the risks inherent in this process. I think it is instructive to review the much greater cost of ignoring the realities of this learning curve. Unfortunately, we have in this Nation a very vivid example of this failure to recognize the realities of commercialization, and that is the experience that we've had in flue gas de-sulfurization scrubbers. Scrubber technology bypassed the essential development process and was prematurely deployed and commercially scaled up in an adversarial atmosphere resulting from legislative and regulatory initiatives intended to provide a quick fix, and that indeed is the paradox, that often our intentions to provide quick fixes backfire and indeed extend both the time frame and the cost of achieving the result.

This brute force approach has involved to date some 50,000 megawatts of electric generating capacity at a total cost of over $20 billion and 15 years in time. Had the flue gas de-sulfurization scrubber technology been developed and deployed in a more rational and cooperative manner, as I believe is now intended under the Innovative Clean Coal Technology Initiative, I believe the cost and capacity required could have been reduced by a factor of 10 with a similar reduced time frame to achieve maturity. In addition, the legacy of poorly operating and obsolete installations and the resulting ill will that exists on the part of the user could have been avoided. I'm particularly encouraged that the private sector response to the Department of Energy's Phase 2 request for expressions of interest has again affirmed the opportunities and commitment to their success, and I believe these opportunities are consistent with the expectations which I conveyed to the committee in my testimony in 1986.

The Electric Power Research Institute, for example, anticipates participating in about 30 Innovative Clean Coal demonstration proposals now under development for submission to Phase 2 of the Innovative Clean Coal Technology Program. The ability to realize these opportunities will depend, however, on several considerations beyond simply funding.

First, the projects selected should emphasize opportunities for both protecting the environment while improving productivity. Thus, it is important that we include technologies for new and repowering applications as well as retrofit control.

Second, realization of confident commercial potential may require several demonstrations to define the application envelope for each technology in the diverse utilization environment that we operate.

Commercial as well as technical success should be carefully examined in the selection process. This should be from the perspective that the Government's role is primarily to expedite the availability of technology for the private sector. Therefore, I'm pleased that the private sector's ability to provide advice and counsel to this effort should be sustained throughout the selection process, and I think the value of this is shown in the improvement in the Program Opportunity Notice for Phase 2 versus that that was available for Phase 1. Also, the Innovative Control Technology Advisory Panel and the National Coal Council have proven to be useful vehicles for this type of advice and counsel to the Department of Energy.

Five, the potential solid waste and water quality side effects of coal use technology will become an increasingly important consideration and certainly should bear heavy examination during the selection process.

Six, the special characteristics of the regulated electric utility industry should be recognized. I think they have been described to this Committee by others and at other times, but I would simply say that the bottom line here is that the risks of new technology application will not be realistically borne by the stockholder unless the opportunity for financial return is commensurate with that risk.

Seven, risk evaluation, therefore, is an important issue in this whole area since the pressure to commercially oversell immature technology in today's market is a growing issue and one which requires careful consideration in the selection process.

Eight, sustained resource priorities and policies—resources, priorities, and policies which provide reasonable confidence that they will survive the development process are important, and I think as we enter into an election year and the uncertainties that follow, it's important that the process reaffirm that these resources, priorities, and policy will be sustained.

And, finally, we need a fundamentally improved scientific basis for, and predictability of, environmental requirements since these ultimately will define, to a large extent, the marketability of the various options.

In conclusion, I believe the Federal Clean Coal Technology Initiatives which you have undertaken can restore the United States position as a world leader in the development, utilization, and export of coal technology products. The effectiveness of these initiatives will depend, however, in my judgment, on whether they embrace, achieve, and sustain these several criteria. In this regard, both the industry and the Electric Power Research Institute will continue working with the Government and other industries to help ensure the success of these efforts intended to further U.S. coal technology leadership as a national resource.

I thank you for your kind attention and would be pleased to address any technical questions you may have.

[The prepared statement of Dr. Yeager follows:]

STATEMENT OF

KURT E. YEAGER
VICE PRESIDENT AND DIRECTOR, COAL COMBUSTION SYSTEMS DIVISION
ELECTRIC POWER RESEARCH INSTITUTE
PALO ALTO, CALIFORNIA

TO
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
HOUSE SCIENCE, SPACE & TECHNOLOGY COMMITTEE

MARCH 2, 1988

INTRODUCTORY STATEMENT

Mr. Chairman, Members of the Committee: I am Kurt E. Yeager, Vice President and Director of the Coal Combustion Systems Division of the Electric Power Research Institute (EPRI).

I appreciate this invitation to discuss Clean Coal Technology and its implications for electricity supply and environmental improvement. This program is especially significant for the electric utility industry, and therefore is of great importance to EPRI. EPRI was established by the electric utility industry in 1972 to conduct a broad research and development program for the entire electric utility industry and its ratepayers. EPRI's R&D mission is to develop new and improved technologies for electric power production, delivery and use, and to help accelerate their availability insuring an adequate supply of economic, reliable and environmentally acceptable electricity.

Current environmental control capabilities must be improved by reducing capital and operating costs and preserving overall plant productivity. The importance of this effort is underscored by the fact that a new, large, conventional coal-fired power plant will typically cost $1.5 billion, with over 30% of this cost being directed toward environmental control. This includes sulfur dioxide (SO_2) scrubbing, particulate control, solid waste disposal, water treatment and plant cooling. These controls in their current form also have a major impact on plant efficiency and reliability.

Recent government initiatives to spur development and deployment of clean coal technologies offer welcome confirmation of the strategic importance these technologies hold for the utility industry and the nation. After more than a decade of rising electricity costs and unresolved debate over environmental issues it is clear that we need technologies that use coal more cleanly and economically.

These goals must be pursued simultaneously. Our economic competitiveness in the global market depends on the continued availability of low-cost electricity from coal. And environmental improvements are sustainable in the long run only if they are part of an economically viable system. An intelligently planned and developed program in clean coal technology can provide a win-win solution-one that responds to the legitimate environmental concerns of society, while keeping the cost of electricity low.

EPRI and the electric utility industry have already spent more than a billion dollars ushering clean coal technologies toward commercial maturity. The approach is broad, encompassing improved methods of extracting impurities from coal before it is burned and innovative designs for new power plants that will produce fewer emissions, while improving the cost-effectiveness and productivity of coal utilization. Less costly and more effective retrofit emission control options are also being developed in the event that environmental science indicates the need for their application. Equally important as these process developments are the rapid advancements being made in power plant materials and in harnessing the microprocessor revolution for improved monitoring and control. Ultimately, we may witness the evolution of coal refineries capable of producing virtually no wastes and extracting chemical feedstocks, fuels, strategic metals, and other coproducts from coal in addition to generating electricity.

The utility industry thus stands at the threshold of fundamental change in its technologic base. But this change does not come easy. New technologies must be developed, tested, and refined in the laboratory, at pilot scale, and in commercial-size demonstrations under a range of conditions before they will be accepted in the market. Such efforts require money, time, and a sustained commitment from utilities, equipment vendors, regulators, and government. The shared commitment to both the Cool Water IGCC facility and the demonstration of an array of commercial fluidized-bed combustion power plants reflects the progress that can be realized. EPRI is particularly proud of its role as catalyst in making this progress possible.

The current pause in capacity expansion offers the United States an opportunity to bring to commercial readiness the next generation of coal-based power technologies. They must be clean, modular, quick to build, and cost-effective. EPRI and the utility industry will continue to support work in this field but cannot succeed alone. Only with national support for demonstration and deployment, and with cooperation from all sectors in encouraging commercialization of innovative technologies can the full promise of clean coal technology be realized.

THE NEED FOR INNOVATIVE CLEAN COAL TECHNOLOGY

Simply stated, "clean coal technology" is intended to reduce the policy conflict between coal use and the environment. It has evolved over the past decade into a family of precombustion, combustion, and post-combustion processes intended to provide the coal user with additional technical flexibility to resolve the conflict in an environmentally holistic manner, at the lowest possible cost. The national benefits of applying innovative clean coal technologies include:

- Decreased cost of producing energy from coal.
- Significant environmental improvements.
- Improved international competitiveness of U.S. technology and coal.
- Reduced reliance on imported oil.

In order to reduce the disadvantages facing conventional coal-fired power plants, clean coal technology development in the United States has pursued two primary objectives; viz., to

A. Provide improved coal utilization alternatives for both repowering and new plant applications. These combine high levels of emission and effluent control with reduced costs and improved thermal efficiency. Fluidized bed combustion and coal gasification are examples of technology addressing this objective.

B. Provide an array of retrofittable emission control options which satisfy, at reduced cost, the void between present physical coal cleaning capabilities and flue gas scrubbing for existing power plants.

These objectives are geared to national, not just regional technology requirements. However, an important distinction should be recognized between these two objectives and the technologies they represent. The first has the potential to reduce the absolute cost and increase the productivity of power generation. The second objective, on the other hand, can only limit the cost increase which would otherwise be imposed by more expensive retrofit controls.

Figure 1 indicates the general cost and performance envelope for these two Clean Coal Technology objectives relative to commercially available options, specifically flue gas desulfurization and physical coal cleaning. Table 1 organizes the various advanced clean coal technologies into six general categories and summarizes their major risk factors which must be resolved through the demonstration process. In addition, it suggests the approximate number of demonstrations and associated cost to address the range of design and operating conditions necessary for confident commercial application decisions.

The key question which must be resolved before large scale application of these options can occur is proof of their long-term reliability under utility operating conditions. The EPRI program, therefore, stresses the development and demonstration of these options at sufficiently large scale to verify their commercial reliability.

Cool Water integrated gasification combined cycle (IGCC) and the three atmospheric fluidized bed combustion (AFBC) demonstration projects being led by the utility industry and EPRI provide effective models for these technology demonstration efforts necessary to accelerate clean coal technology. EPRI has been pleased to be a partner in these projects and looks forward to continuing its cooperative efforts, where financially possible, to stimulate the prompt acceptance of improved technology.

Figure 2 indicates the characteristic learning curve associated with the development and commercial deployment of new technology. Today, the various advanced clean coal technology options under consideration have reached, or are approaching, first commercial demonstration. It is this "commercial demonstration" step where the size and cost of the facility necessary to assure reliable operation is the greatest. As the learning curve continues, each succeeding installation entails less risk and therefore less engineering margin and redundancy until full commercial maturity is reached. It is recognition of the risks inherent in this learning curve, and the need to share in the cost of their resolution, which defines the need for the National Clean Coal Technology Initiative.

A case study of the much greater cost of ignoring commercialization risk is the forced deployment of flue gas desulfurization (FGD) scrubber technology in the U.S. This resulted in an exception history of cost and inefficiency as indicated by Figure 3. Contrary to sound development practice, FGD scrubber technology bypassed the scale-up process of development and was prematurely deployed at commercial scale as a result of legislative and regulatory requirements. The deployment process occurred in an adversarial atmosphere where the incentive was on least first cost without adequate understanding of, or insurance against, the performance and reliability risks involved. As a result, this "brute force" approach to development and deployment has involved over 50,000 MW of electric generating capacity at a total cost to the utility industry and rate payer of over $20 billion (1987 $) in capital, operating and lost generating capacity costs during the past 15 years. Only now is the technology approaching acceptable reliability, although at an excessive cost for operational risk protection and redundancy which still requires substantial development attention.

Had FGD scrubber technology been developed and deployed in a more rational and cooperative manner consistent with the pattern of Figure 2, the cost could have been reduced to $1-2 billion involving no more than 2000 MW of capacity, with no delay in the time frame necessary to achieve maturity. In addition, the legacy of poorly performing or obsolete commercial, scrubber installations and the resulting ill-will on the part of the user could have been avoided. One need look no further than the Japanese experience with FGD scrubbing technology to see the contrasting success and cost/effectiveness of the more rational, cooperative approach to risk shared development and deployment.

FACTORS BEARING ON PROJECT SELECTION

The response to DOE's November 1986 Phase II Request for Statements of Interest concerning Clean Coal Technology demonstration projects again affirmed these technical opportunities and the private sector commitment to their success. 137 expressions of interest were provided with potential private-sector cost sharing exceeding $2 billion. This compares quite favorably with the 175 projects originally identified in February 1985, in response to the Phase I DOE Clean Coal Demonstration solicitation.

Table 2 categorizes these 137 submissions by technology. The number of retrofittable flue gas cleanup and coal preparation demonstrations is particularly noteworthy since neither of these categories was well represented in the projects selected by DOE during Phase I of the Clean Coal Demonstration Initiative.

EPRI anticipates participating in about 30 innovative clean coal demonstration proposals under Phase II of the DOE Innovative Clean Coal Technology Demonstration Program. The total cost of these proposed demonstrations is expected to be on the order of $2.5 billion and will include technology opportunities in coal preparation, wet and dry flue gas desulfurization, combustion and postcombustion NO_x control, fluidized bed combustion and coal conversion.

As in Phase I, the nation's ability to realize these opportunities will depend on the policies used by the Administration and Congress. I am therefore pleased that the DOE solicitation for Phase II is more responsive to the suggestions and concerns of the private sector. It is important, however, that the following considerations be emphasized during the demonstration selection process:

- The projects selected should emphasize opportunities for protecting and improving productivity while reducing emissions. In our experience, the commercial acceptance and rate of implementation of clean coal technology in the electric utility market depends on these combined capabilities rather than focusing only on emissions reduction.

- Realization of commercial potential may require several demonstrations of each technology type. In the electric utility industry, where reliability is a paramount consideration, complementary demonstrations addressing the range of design, fuel, supplier, and operating variables faced by the user will be necessary to achieve confident, and cost competitive commercial application. Therefore, in order to achieve the broadest and most rapid commercial application, government funding should seek to competitively leverage the greatest number of projects supporting the goals of the program. Using market incentives in this manner would also be expected to result in substantially more "bang for the federal buck" in terms of emission reduction achieved as well as the number of projects realized and cost sharing required.

- Each proposed demonstration should be carefully examined in terms of its potential for commercial as well as technical success. This examination should be from the perspective that the government's role is primarily to expedite technology for use by the private sector. Thus, in addition to the factors which relate to demonstration success, DOE should carefully consider the ability and desire of the target industries to utilize the results of each project. These considerations will affect the information requirements in the demonstration solicitation accordingly. In this regard, the requirements should be sharpened and simplified and should, above all, encourage the greatest possible response.

- EPRI strongly endorses the concept of obtaining and using industry advisory input at every stage in the Innovative Clean Coal Technology Program. The collective insight of DOE's Innovative Coal Technology Advisory Panel (ICTAP) and the National Coal Council, for example, have proven useful as an has proven useful as an advisory structure for specific solicitation language, the market potential of technology alternatives, and the adequacy of projects to meet the needs of the market. We have found at EPRI that such broad advisory participation is often the key ingredient where success is ultimately measured by commercial acceptance.

- The potential solid waste and water quality side effects of air pollution control technology will become an increasingly important consideration in cost-effectiveness and commercial acceptance. We therefore strongly endorse the use of this important criterion for demonstration selection.

- Many promising energy technology developments are highly proprietary and result from years of corporate effort. Federal patent and data rights provisions therefore discourage utilizing government support for highly promising proprietary technology, with the net result that solicitations seldom attract the most advanced projects. To be effective, government must reinforce, not replace, the private market forces building our energy economy. This can best be accomplished as a risk shares in private sector initiatives performed in the national interest. The return on this risk sharing is the cost reduction to the nation achieved through accelerated commercialization of more productive technology.

- The regulated electric utility industry, which is the primary domestic user today for coal technology, lacks the incentive of economic reward to commercialize the technology whose development it has vigorously supported. When coupled with the substantial technical, financial, and regulatory risks associated with the full scale commercialization of new coal utilization technology, innovation can be stifled.

  These risks can be generally classified into four broad categories:

  - Technical uncertainties involving performance at specified levels and duration and projected costs.

  - Market uncertainties caused by uncertain future load growth and competition from currently less expensive fuel options.

  - Regulatory uncertainties that expose shareholders to unexpected, after-the-fact financial risks, and which encumber a project's revenue stream needed to pay financing charges and repayment of debt.

  - Environmental uncertainties which may mandate compliance to levels and within time frames that effectively preclude innovative coal technology or render it obsolete after the fact.

Unless these risks are reduced and economic and/or regulatory incentives are adopted, the deployment of new coal technology will be constrained. Technological leadership as well as the ultimate equipment supply base will then likely pass to other nations that more effectively pursue this objective.

CRITERIA FOR SUCCESS

The development and demonstration of atmospheric fluidized bed combustion (AFBC) for application to coal-fired electric utility power generation, provides an instructive example of the development of clean coal technology from small-scale testing to the threshold of broad deployment.

Hindsight can provide valuable perspectives to guide decisions that we must make today and in the near future. Based on EPRI's experience with AFBC over the past 15 years, we suggest the following key criteria for successful technology development, scale-up demonstration and deployment.

1. Step-by-Step Evolution. Scale-up factors must be realistic, reflect the current understanding of the technology, and recognize the unresolved technical issues. In view of the chemical and mechanical complexities of most clean coal technologies and the heterogeneous, variable characteristics of the feedstock (coal), a scale-up factor greater than 10 to 1 should set off alarm bells - i.e., the technical and financial risks should be explicitly recognized and weighed against the incentives to take shortcuts. In the development of coal utilization technologies, the shortcuts have a poor track record.

   While history supports the advisability of a stepwise development path, under the right circumstances the steps need not be strictly sequential. In some cases, "leap-frogging" or overlapping the steps can be a rational way to accelerate technology evolution. For example, a project team might plan, site, and begin design of a full-scale demonstration while the testing of the intermediate-scale prototype is still in progress.

2. Testing at Each Step. Every development project up to and including full-scale demonstration should include testing. While this criterion is taken for granted at small scale, it can sometimes be forgotten in the planning of a large-scale demonstration. The major part of the funding of a demonstration project is necessarily devoted to construction. However, the completed plant must be viewed only as a vehicle for achieving the real purpose of the demonstration process: to provide information with which to evaluate performance and cost, to design other plants, to take another sscale-up step if appropriate, and to judge the commercial potential of the demonstrated technology over as broad a range of conditions as feasible.

3. Multiple Projects. One demonstration - even at full scale, including a comprehensive test program, and achieving all its technical objectives - is insufficient to address the commercialization issues. Numerous small-scale fluid bed combustors are operating commerically in industrial application in the U.S., Europe and the Far East, and many more are planned. These industrial FBCs illustrate some of the technology's attractions for large-scale clean coal utilization, and show that many of the technical questions have been answered. Indeed, in the smaller industrial applications the case can be made that AFBC is an "emerged" rather than emerging technology, and the dangerous leap of logic is then to conclude that the full-size scale-up step is all that remains. It is not. In the electric utility industry where reliability is paramount, complementary demonstrations addressing the range of designs, fuels, suppliers, and operating variables to be faced by the user will be necessary to achieve confident and cost-competitive commercial application.

4. Commitment. If the purpose of a development project is to take a successful step in the evolution of the technology, then the incentives of all project participants must be directed toward that success. Organizing a major demonstration project requires strategic thinking far beyond negotiating financial participation, data rights, and milestone schedules. The project's risks must be allocated thoughtfully so that all participants' commitments are based on accurate understanding of their respective exposures. Project failure scenarios should be explored realistically and openly in the planning stage to test the robustness of the financial/technical commitment structure.

   - The allocation of risks and risk management have become an important consideration for EPRI. A major lesson learned is that the technology user cannot avoid risk, regardless of negotiated warranties. The participants in a project must commit the expertise needed to monitor their respective interests throughout.

   - Operator training must start early in a project and include every skill level and trade in the plant. AFBC and other new coal utilization technologies all have unique features, and to recognize that a significant fraction of operators' experience will be obsolete, is to face reality and prepare accordingly.

   - In the current depressed market, the pressure to commercially oversell immature technology is a growing issue which requires more than the usual level of risk evaluation on the part of all demonstration participants. Emphasis must be on prudently sharing risk, not on avoidance by transferring it to others.

COAL TECHNOLOGY FOR THE GLOBAL MARKET

A fundamental problem facing the U.S. is how to remain competitive in an increasingly global economy. Competitiveness is determined by a variety of factors including exchange rates, wages, capital availability, foreign subsidies, trade barriers, energy costs and technology. How can the U.S. resolve the conflict between its geopolitical role and its effectiveness as a world market competitor? The answer is achieving technological advantages that overcome the handicaps associated with high cost production of commodities essential to economic stability and defense. To remain competitive, manufacturers must control costs, improve productivity and offer innovations in products and services not found elsewhere. Maintaining a secure, least cost electric power supply is an essential element of this strategy. Unless we keep electricity costs down to critical industries, our whole economy is threatened.

Thus, in the U.S., the pulverized coal, central station power plant has been largely overtaken by the events of escalating capital cost, environmental concerns, uncertain electric demand, regulatory penalties, and, most of all, growing global competitiveness. New coal utilization technologies that better respond to the uncertainties resulting from these trends will be emphasized to meet the energy demands of the coming decades.

We therefore expect coal-fired power plants to evolve from the present relatively resource inefficient, mechanical combustion units into fully integrated resource refineries (Figure 4). Electric power generation would thus become one element of a broader processing capability. These modular plants, which can synthesize a range of products including fuel, building materials, chemcials, and metals in addition to electricity, will be made possible by a new spectrum of process technology combined with "expert" diagnostic/control systems.

In an increasingly global economy, commercial success in coal technology is likely to pass to those who recognize and implement this strategic vision. The progress of the U.S. in sensing and process control, coupled with integrated coal conversion/power generation, ash processing, dry cooling, and CO_2 recovery provides the building blocks to produce any mix of electricity, heat, liquid or gaseous fuel, plus marketable byproducts required by the local economy and be compatible with the local coal base.

The payoff is not just economic development but resource conservation and environmental protection on a global scale. If, for example, even half the world's expected expansion in coal utilization applied U.S. manufactured equipment, the value to the U.S. by the year 2000 would be on the order of $35 billion per year. The environmental benefits to "spaceship earth" would be profound. Both economic security and geopolitical responsibility encourage the U.S. to provide the national means and will for leadership in the achievement of this goal.

Summary and Conclusions

1. The principle which guides clean coal technology development is that sustained environmental improvement can only be achieved when both emission and cost reduction are achieved concurrently, not pitted against each other. Clean Coal Technology thus provides a unique opportunity to concurrently satisfy two national goals: (a) continue the substantial progress made in emission control by resolving the conflicts between coal use and environmental protection, and (b) meet the rapidly appoaching electricity generating capacity challenge with reduced cost and increased productivity.

2 The inflexibility of proposed emission control legislation tends to discourage the application of innovative clean coal technology and limit freedom of choice. This may substantially increase the cost of compliance and delay implementation of new clean coal generating capacity which combines emission control and cost reduction. The result will be eroded environmental quality and economic productivity, quite contrary to the expectations of the legislation. Flue gas scrubber experience offers a graphic case study of the excessive costs associated with such inflexibility and failure to accept the inherent learning curve associated with all new technology.

3. Success in technology development is founded not only on vision and resources, but also on attention to the lessons learned from experience. EPRI's experience supports the following conclusions:

   - Development, demonstration and deployment of improved technologies for clean utilization of coal must proceed in a stepwise scale-up sequence. While the steps can be overlapped under the right conditions, skipping steps entails severe risks that are usually unacceptable if they are assessed realistically.

   - Any development effort, but especially a full-scale demonstration, must have a serious test program built in that recognizes the application and potential value of the demonstration results beyond the demonstration plant itself.

   - Many, if not most, clean coal technologes will require more than one full-scale dmeonstration to address the technical issues and evaluate performance sufficiently to further the goals of broad deployment.

   - Commitment from all project participants, built in incentives for success, and mutual understanding and acceptance of the respective risks is critical to achieving the commercialization objectives. All these factors must be addressed at the outset in the planning stage.

4. Although the United States has historically been the world leader in coal technology, and the projects it makes possible, this leadership is being eroded by nations which encourage a more cooperative relationship between industry and government, and maintain their strategic focus on the commercial importance of coal technology.

   Based on U.S. experience, and considering the efforts in competing countries, the necessary government role should provide a clear mandate to support, in the national strategic interest, the demonstration and commercial deployment of advanced coal technology and the competitiveness of the supplying industries. This mandate would include:

   - Closer cooperation with supplying and using industries to expedite technology advancement, and elimination of the all-too-often adversarial approach to government/private sector development and commercialization efforts.
   - Significant and sustained financial resources and priorities that recognize the national security and commercial importance of coal technology.
   - Ability and commitment to act as a risk sharing investor in coal technology projects initiated and managed by the private sector and in the public interest.
   - Elimination of counterproductive regulatory and cost recovery constraints on the use of innovative technology at both the federal and state level. This is of particular importance to the regulated electric utility industry where opportunities abound to demonstrate the commercial worth of advanced coal technology.
   - A fundamentally improved scientific basis for, and predictability of, environmental requirements. This would significantly reduce the market uncertainty associated with coal and the technology for its use.

5. I believe the federal "Clean Coal Technology" initiatives can restore the United States' position as a world leader in the development, utilization and export of coal technology products. The effectiveness of these initiatives will depend, in my judgement, however, on whether they embrace, achieve, and sustain the several criteria outlined above. In this regard, the electric utility industry and EPRI will continue working with both government and other industry to ensure the success of efforts intended to further U.S. coal technology leadership as a national resource.

Thank you. I would be pleased to address any technical questions you may have.

Figure 1

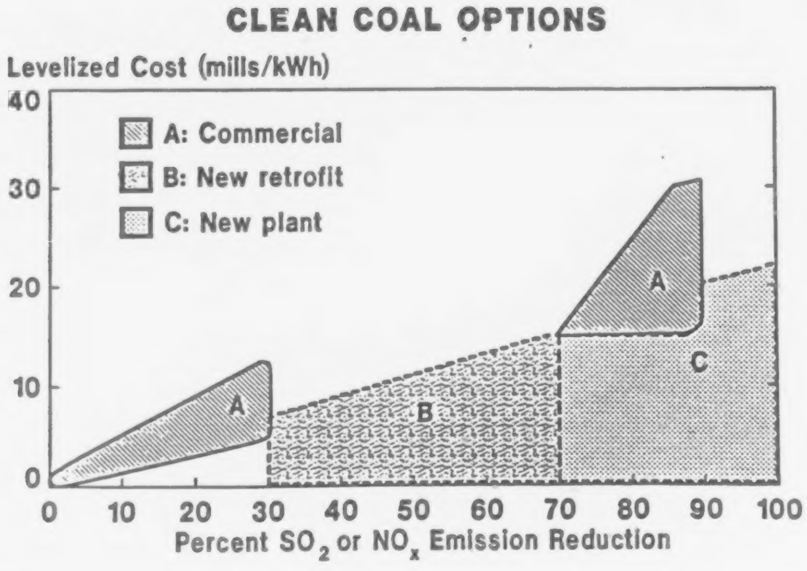

CLEAN COAL OPTIONS
Levelized Cost (mills/kWh)
40
30
20
10
0
A: Commercial
B: New retrofit
C: New plant
A
B
A
C
0
10
20
30
40
50
60
70
80
90
100
Percent SO_2 or NO_x Emission Reduction

TABLE 1

CLEAN COAL TECHNOLOGY APPLICATIONS AND RISKS

Technology	Capital Cost ($/kW)1	Net Cost Effectiveness ($/Ton SO_2 OR NO_x Removed)	Application Retrofit	 Repower/ New	Risk Factors	Additional Demonstrations Needed	Cost (M$)
1. COAL CLEANING AND UPGRADING							
a. Advanced Physical Coal Cleaning	60-100	400-600	X	X	• Degree of sulfur removal • Btu recovery • Increase in coal moisture • Economic agglomeration technology	5	$200
b. Low-Rank Coal Upgrading	10-60	300-800	X	X	• Capital cost of equipment • Btu recovery • Product quality • Increase in coal moisture	3	$150
2. WET FLUE GAS DESULFURIZATION							
a. Conventional FGD	400-450	825-1200					
b. Advanced Conventional FGD	250-275	450-650	X	X	• Capital costs of redundancy and materials • O&M cost savings through elimination of reheat	6	$140
c. Advanced Regenerable FGD	550-650	650-850	X	X	• Capital costs of materials and redundancy • O&M costs associated with membrane plugging, sorbent use	5	$180
3. DRY SO_2 CONTROL							
a. Furnace Sorbent Injection	50-75	800-1000	X		• Boiler impacts • ESP upgrade costs • Waste management	3	$30
b. Duct Sorbent Injection	50-100	500-1000	X		• Duct deposition (calcium systems) • Baghouse performance (hybrid system) • Soluble wastes, NO_2 plume, sorbent cost and availability (sodium system) • Particulate control/humidification • Waste management	8	$50

Technology	Capital Cost ($/kW)[1]	Net Cost Effectiveness ($/Ton SO_2 OR NO_x Removed)	Application		Risk Factors	Additional	
			Retrofit	Repower/New		Demonstrations Needed	Cost (M$)
4. NO_x CONTROL							
a. Combustion Modification	5-35	100-1000	X	X	• Effects on carbon burnout, flame stability, slagging and corrosion	3	$15M
b. Post-Combustion NO_x Control	75-100	1000-4000	X	X	• O&M costs of catalyst replacement • Availability loss due to air heater cleaning	3	$60M
5. FLUIDIZED BED COMBUSTION							
a. Atmospheric	300-1600[2]	200-500[3]	X	X	• Capital and O&M costs of heat transfer surface and solids handling systems	2	$300M
b. Pressurized	800-1500[2]	200-450[3]		X	• Capital costs as per AFBC • O&M costs of sorbent utilization and gas turbine maintenance	2	$400M
6. INTEGRATED GASIFICATION COMBINED-CYCLE	1300-1900[2]	200-400[3]		X	• Capital costs of design conservatism • O&M costs of heat transfer fouling, refractory & sulfur recovery • Availability loss during startup	3	$750M

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1 For an approximately 250-MW retrofit/repower unit to burn medium- to high-sulfur coal (2.5-4% sulfur). In 1986 dollars.

2 Total installation cost range reflects repower and new applications.

3 Net SO_2/NO_x control cost effectiveness based on fraction of total capital and operating costs assigned to emission control.

Figure 2

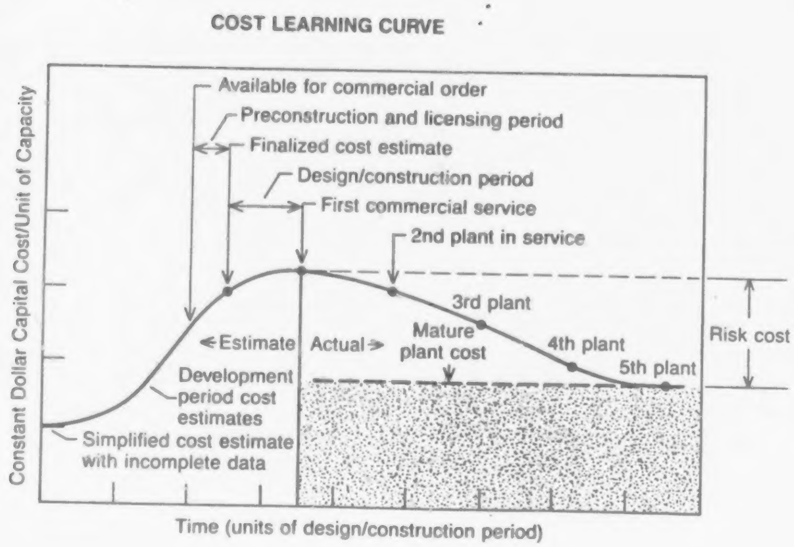

COST LEARNING CURVE
Available for commercial order
Preconstruction and licensing period
Finalized cost estimate
Design/construction period
First commercial service
2nd plant in service
3rd plant
Mature plant cost
4th plant
5th plant
Risk cost
Estimate
Actual
Development period cost estimates
Simplified cost estimate with incomplete data
Constant Dollar Capital Cost/Unit of Capacity
Time (units of design/construction period)

Table 2

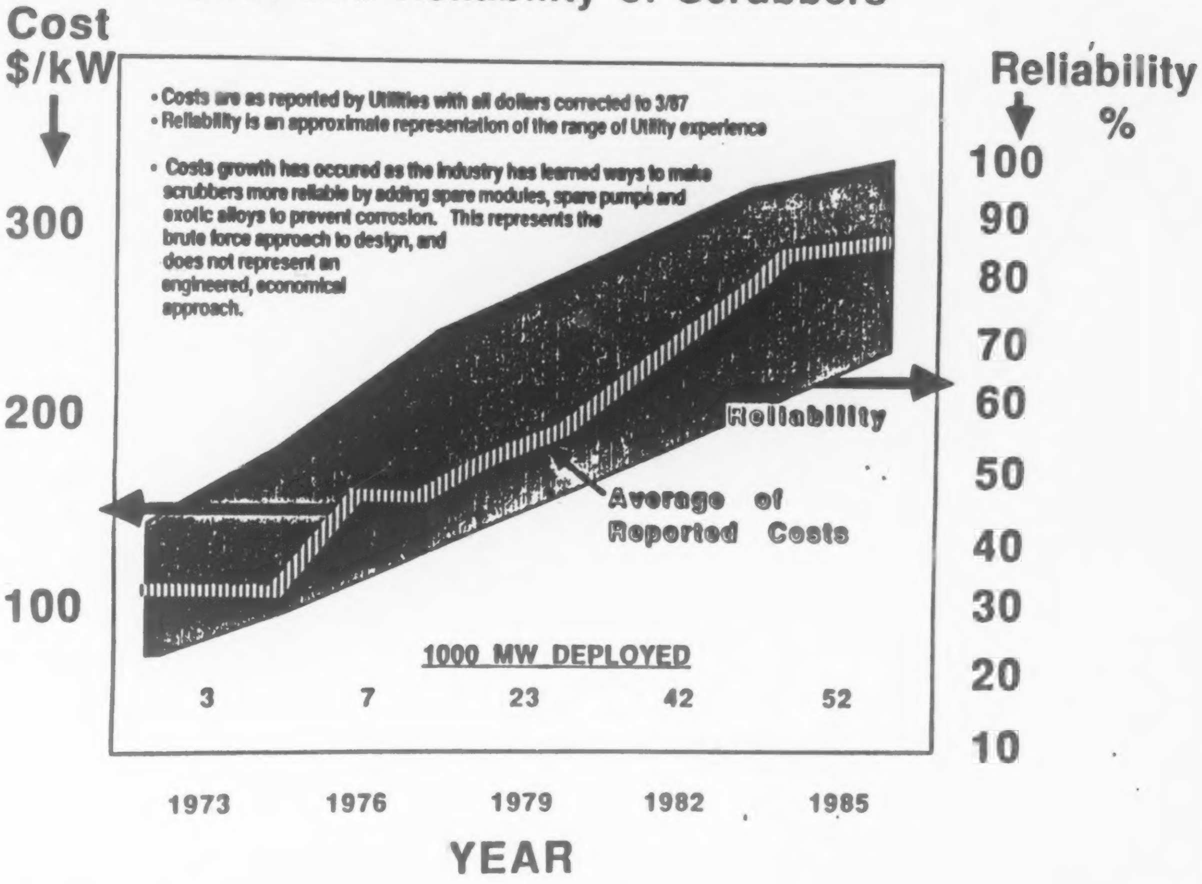
PROJECT SUBMISSIONS RECEIVED BY DOE
Categorized By Technology

Technology	Number	Total Value* ($ x 10^6)
Flue gas cleanup	49	706
Coal preparation	25	409
Fluidized-bed combustion	15	1072
Advanced combustors	13	230
Alternative fuels	13	218
Surface coal gasification	11	1903
Non-technology specific	3	25
Coal-fired turbines	3	62
Industrial processes	3	57
Coal liquefaction	2	71
Fuel cells	1	6
MHD	1	400
	139	5159

*5 of the submittals did not provide cost information

Figure 3

Cost and Reliability of Scrubbers

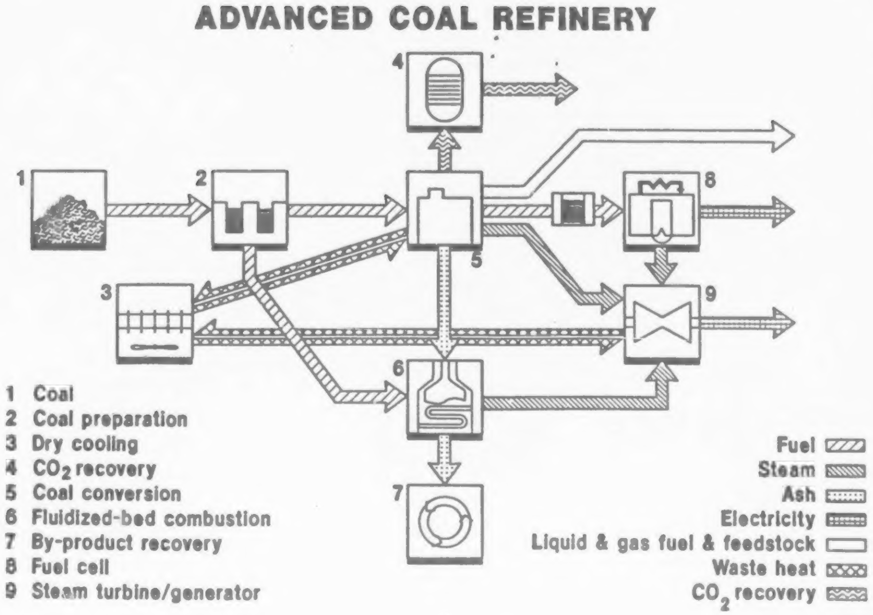


- Costs are as reported by Utilities with all dollars corrected to 3/87
- Reliability is an approximate representation of the range of Utility experience

- Costs growth has occured as the industry has learned ways to make scrubbers more reliable by adding spare modules, spare pumps and exotic alloys to prevent corrosion. This represents the brute force approach to design, and does not represent an engineered, economical approach.

Cost
$/kW
300
200
100
Reliability
%
100
90
80
70
60
50
40
30
20
10
Reliability
Average of
Reported Costs
1000 MW DEPLOYED
3
7
23
42
52
1973
1976
1979
1982
1985
YEAR

Figure 4


ADVANCED COAL REFINERY
1
2
3
4
5
6
7
8
9
1 Coal
2 Coal preparation
3 Dry cooling
4 CO_2 recovery
5 Coal conversion
6 Fluidized-bed combustion
7 By-product recovery
8 Fuel cell
9 Steam turbine/generator
Fuel
Steam
Ash
Electricity
Liquid & gas fuel & feedstock
Waste heat
CO_2 recovery

PANEL DISCUSSION

Mr. **Boucher**. Thank you very much, Dr. Yeager and Mr. Yamagata.

Mr. Yamagata, in your statement you suggest that the enactment now of an acid rain control program would preclude or inhibit the development of clean coal technologies, and yet there are people who are advocating an acid rain control program who suggest that, given the time frames that such a program might contain for achieving certain levels of compliance, that by that time there would be in effect in commercial use a sufficient number of clean coal technologies to assist in compliance. So how do you respond to that claim?

Mr. **Yamagata**. I think, Mr. Chairman, that one has to first make the statement, as I will, that we have some question about the need for such a program, but aside from that issue in itself, it goes without saying that the whole issue of acid rain control is very much a topic of consideration in another committee that you serve on at this very time.

With respect to whether or not clean coal technologies can be integrated into a control program, you also correctly noted that it is our belief that to try and do both and to integrate a technology development program into a control program simply won't work.

The reason why we say that is because, under certain types of control programs like the ones, I believe, that are being considered in the Energy and Commerce Committee, there are very specific dates as to when compliance must take place.

Our position in the past has been and continues to be that you cannot, and the utility industry will not, plan to control a specific facility twice, that is, once perhaps by coal switching, to then be retrofitted with some kind of available control technology that might be available some time in the future.

The options available for utilities particularly, at least at this time, will be with the available options they have now, which is to switch, to utilize existing scrubbing technology, or simply to shut down facilities.

Until we have a better understanding, and that is, until these technologies are at a commercial ready state, the utility industry cannot take the chance of utilizing them, and the problem that we've got today is that they are not at that commercial ready state.

Now there will be differing opinions as to when that commercial ready state will take place, but I think you heard from the Department of Energy today that even that first technological demonstration of technologies isn't likely to happen until the mid-90's, and the point that we have been trying to make is, one, if you look at the learning curve, which I think I set out in my written testimony on about page 4, that suggests that that first technically-proven demonstration is at the highest cost of the learning curve.

What you ought to be trying to do is to support enough of those additional demonstrations to bring the cost of that technology down to a point where it is both technically feasible and economically viable, and we need to get to that economically viable state in order to use those technologies. Now I don't think we're there yet, and we're not likely to get there, I believe, with many technologies, and perhaps Dr. Yeager can define the state of those technologies better than I, but we're not likely to get to that state of commercial readiness until the end of the 1990's on most of these technologies.

Mr. BOUCHER. I guess I kind of wonder as well what incentives are there for utilities to employ the technologies even when they are proven to be workable? If you don't have an acid rain control program in place that imposes emission reduction requirements, why are the utilities going to go out and spend a lot of money to install these new technologies on the pre-1977 plants?

Mr. YAMAGATA. I think that Dr. Yeager correctly, I would agree, identified the two different kinds of technologies that we need to look at in the context of the question you asked.

With respect to retrofit technologies, it would be fair to say that where the utility industry, in particular, is not required, except for State programs, to control emissions any more than current law requires, there should be, and understandably so, very little impetus to retrofit emission control technologies on those facilities, because the only thing you're doing is lessening the revenues from that facility. You might be lessening the emissions, but there is no legislated or legal requirement to do so.

Our position with respect to those kinds of technologies is that it is a prudent course of action to attempt to develop those technologies to the state of commercial readiness. The Government has undertaken since 1978, I recall, a program to determine through scientific inquiry what kind of problems may exist with respect to emissions and whether or not existing law needs to be changed to more greatly control those emissions. Until that scientific inquiry is completed, it doesn't seem to make good public policy sense to be legislating conclusions before the conclusions are in.

To the extent, however, that it makes prudent sense to develop technologies that are more cost-effective to the consumer, that ought to be done, and that is being done, through an aggressive retrofit program.

With respect to the repowering technologies or the new applications of technologies that Dr. Yeager referred to, there would be economic incentive to do so first of all because those technologies are likely to be cheaper in comparison to the available options we have today and, as importantly, many of them, for example, with respect to pressurized fluidized bed or gasification technologies, they are projected to be much more effective in terms of emission control and for the same price as we have today.

So if you assume, as we do, that by the turn of the century, if not sooner, there is going to be a need for additional electric capacity, there is also need for, on an economic basis, need for these new technologies.

Mr. BOUCHER. Well, I think with respect to repowering you've perhaps answered the question. It may be economically efficient to rebuild the generator or the boiler or what-not, and where a direct savings can be experienced there, obviously the incentive exists to do so, but I'm not sure with respect to retrofit that you really have answered it. What incentive is there for the utility to spend a lot of money, even though the clean coal technology is available, in the absence of some mandatory emissions reduction program? I think that question is still outstanding.

Mr. YAMAGATA. And I don't disagree with you. I would say that we need to wait and see what kind of submittals we're going to get off the second round of clean coal technology proposals. That should tell us something about the interest of the utility industry in those proposals. And I would underscore again, Mr. Boucher, the need to develop the technologies. Now whether or not the industry has an incentive to do the demonstrations is the first step we must take. Once we get past that step, then presumably we'll have some better idea, given time, what scientific inquiry is going to tell us about the need to commercially utilize those retrofit technologies, but we ought to have them in place, if possible, before we have to answer that question.

Mr. BOUCHER. Let me pass on to the question of the level of funding. You've got for fiscal year 1988 $50 million which will be expended for demonstration projects; for fiscal year 1989, $525 million; that's already appropriated and assured. Now the Administration is asking for the time frame fiscal year 1990 through 1992 an additional $1.77 billion. That's over and above this amount of $275 million—$575 million, which is already assured.

Now I guess my question is, that's an enormous addition to the program. It's by orders of magnitude greater than what is available today. It's greater than anything that I've heard your Coalition suggest was appropriate for this kind of program. Can that amount of money be spent efficiently within that timeframe for a demonstration-scale program?

Mr. YAMAGATA. Mr. Chairman, in our statement, in our written statement, we indicated that the Coalition has been on record in support of a multi-year program of both demonstration and deployment that reflects our support for the President's initiative and an initiative that Senator Byrd instituted in the Senate last year in the form of Senate bill S. 879.

However, we also indicated in our written testimony and in my oral statement that the additional amounts of funding being requested by the President, at least with respect to our support, has to be done with several caveats. One is, we are not certain about the amount of funding required; nor are we certain at this point in time about the time frame of which those fundings ought to be made available. In S. 879, for example, that legislation calls for a funding level of about $350 million over 10 years. All of that requires additional consideration.

More important, however, as I hope we emphasized in our testimony, in order to utilize those kinds of dollars, which I think we can say would be necessary, the Congress and the Administration ought to take a close look at the direction and the scope of future Program Opportunity Notices. A lot of that, I think, gets embodied in the deployment program that I described in my testimony.

Mr. BOUCHER. Well, on that note, let me simply say that it's been my understanding all along that what we're talking about is a demonstration program that we are not forecasting a movement by the Government into a deployment program where we would help to fund the installation of these technologies utility-by-utility around the country. What we're trying to do is demonstrate its commercial scale, the workability of the technologies that have been proven at some earlier stage of the research process.

Mr. YAMAGATA. Yes.

Mr. BOUCHER. You're not suggesting any departure from that basic notion, are you?

Mr. YAMAGATA. I'm not suggesting a departure from the basic notion. What I did suggest in my testimony was, you can support the construction and operation of the first demonstration facility, and this Committee and others in the Congress have done that in the form of projects like Cool Water in California and other places.

But what happens after you develop that first demonstration project, if it's successful, it's going to tell you something about technical feasibility. That project, on a simple learning curve, is also going to be very costly, because you're going to over-engineer, put too many bells and whistles on that technology. What you need with respect to widespread commercial use of that technology is to be able to bring the cost of the technology down to the point where it is a commercially-mature technology—in other words, bring it to the gate of commercialization.

Mr. BOUCHER. Yes. We all agree, though, that a part of bringing the cost down does not include some kind of Government supplement for the actual deployment of the technology after the demonstration is complete.

Mr. YAMAGATA. It depends on what you mean by the word "deployment." Again, I was trying to emphasize in my testimony that there has been considerable confusion about deployment. Many people think that deployment is widespread Government subsidization of technologies wherever an industry might have an interest in utilizing them. We don't agree with that. What we do agree with, however, is that you move beyond that first technically-demonstrated project to a point—that is, with the subsidization of further projects—to the point where that technology is commercially mature. It's going to take more than one project and more than one demonstration to convince a utility that is absolutely risk averse that they ought to use that technology.

Mr. BOUCHER. That's a clever use of words——

Mr. YAMAGATA. Thank you.

Mr. BOUCHER [continuing]. And it sounds to me like—you're welcome, and you're good at that. But it really sounds to me like what you are, in fact, suggesting is a program of Government subsidization for the deployment of these technologies, and I'm not for that. I think that is way beyond the scope of what we had in mind when we authorized this program and when many of us went to the Floor and urged appropriations for it, and I can say to you that I would resist any effort to see the Government involved in what amounts to financing the installation of these technologies utility-by-utility around the country.

Well, that concludes my questions. I've way overused my time.

The gentleman from Connecticut, Mr. Morrison. I'm sorry.

Mr. MORRISON. Even though you won't want to hear it, gentlemen, I'd have to agree with our chairman. We've gone through a number of wrestling matches on both demonstrations and deployment, and I also sort of sense that you are going to get some regulatory world that's going to push some things, but I understand your arguments—in fact, respect both of the groups, the Coalition, and EPRI has been very, very important to us, and I commend you for your work and for your statements.

Let me just accept the input that you're making in your statements and go to something that is perhaps a little broader-based. I find some rather interesting levels of evaluation now of things like the greenhouse effect and am wondering if, as representatives of a number of people in the coal-burning arena, how I answer some of my constituents on what we're doing to ourselves as far as the accumulation of carbon materials in the atmosphere and what we're doing. Do you have some answers to some of the scientific findings that justify the expanded burning of fossil fuels?

Dr. YEAGER. Well, I would make a couple of comments in that regard. First of all, as the science is understood today, the rate of change, and what is driving the change in the case of any climatological excursions is not at all clear, so that the issue of steps that ought to be taken today in that regard are certainly unclear.

Secondly, it is clear that, whatever we decide in that regard, it's going to have to be an international initiative. The United States and, in fact, the Western industrialized world is becoming an increasingly minor player in the dimension of carbon modification in the atmosphere and in the environment. So I think it raises a number of policy issues that make issues such as acid rain look like child's play by comparison when you look at who stands to gain and lose in the international environment by climate change and the implications of northern hemisphere-southern hemisphere relations, so that that all brings to bear on the issue.

I think that as we look at technology, setting all that aside, and where the technology ought to be going, that we ought to be driving for technology that is holistically responsive to environmental issues which involve climatological change. Some of those are, as you noted, greenhouse gases which go well beyond CO_2; CO_2 itself may be a difficult proposition to deal with. Other gases that are resulting from the combustion process may be more approachable in technology in an economic sense, and we're putting a good deal of emphasis into that.

Certainly the opportunities in coal conversion, for example, provide one of the more strategically important opportunities to capture that. In my testimony I indicate the concept of the coal refinery, which is where I think we're ultimately heading with coal technology, in which the process is a series of building blocks of technology tied together by what is really a remarkable revolution in command and control and instrumentation that's going on in this country and where I think strategically our commercial interests are best served. That is a technology not only for this part of the world but one which we can, I believe, strategically work towards selling overseas as a fundamental resource base for developing countries as well, and I can assure you that other nations that's not a unique concept of mine. I wish I could take authorship for it, but I certainly can't. Other countries which maintain a more strategic perspective on their energy policy are certainly pursuing this kind of a dimension.

So that is a fairly broad-gauged response to your question, but I think the bottom line is that that is an issue which we certainly are trying to take advantage of in Clean Coal Technology and that the evolving technologies which we believe should take first priority in such a program are those that are best designed to address those issues.

Mr. MORRISON. Thank you—an excellent answer. I appreciate that, and I just share with you, one new group at least has been formed in the Congress to look at this sort of thing, so I know it will increasingly be an issue in front of us, whether Dr. Sagan participates or not.

Thank you very much, Mr. Chairman. That's my only question.

Mr. BOUCHER. Mr. Kanjorski.

Mr. KANJORSKI. Mr. Chairman, I have no questions.

Mr. BOUCHER. Well, gentlemen, we appreciate your testimony here. I'm going to ask just one additional question, and that is this, and it stems from a parochial concern that I have. I represent an area of the country that produces low-sulfur coal, and there is still some concern in the low-sulfur coal community that clean coal technology is not entirely in their best interest because they will make more efficient and economically attractive the burning of high-sulfur coal. Do you have a response for them? Can you point to some of the emerging clean coal technologies that are really more geared for their industry and that would encourage the greater use of low-sulfur coal at the same time?

Dr. YEAGER. Well, I like to think of clean coal technology as being an equal opportunity technology base, and that's one of the reasons why there is such an array of technology, and I suspect for you gentlemen and ladies occasionally it's a little bewildering that there's a lot that gets captured under this heading of clean coal technology.

In terms of specific activities, one has to remember again that clean coal technology and the issues driving it are going well beyond sulfur, and technologies of interest today deal with other issues in the combustion of fossil fuels in addition to sulfur; nitrogen, oxides, in particular. Clean coal technologies provide that base. I'm afraid that if we don't hang together in the coal business we may all hang separately, because we may find that sulfur was yesterday's issue. The issues that are really driving the environmental programs—and I would say that the bills that are under consideration in the Congress today, are driven by issues increasingly other than sulfur but which have very important implications for both high- and low-sulfur coal use.

Also, the issue of low-sulfur becomes a very relative term. What is low-sulfur? As one looks at some of the requirements that are being contemplated on the controls of sulfur, there is no such thing as a sufficiently low-sulfur coal. So that, again, the advanced technologies, fluid bed combustion, coal gasification in particular, are technologies which are, I think, just as viable and just as important to the markets for low sulfur coal as they are for high-sulfur coal.

Mr. BOUCHER. So you're suggesting that fluidized bed, for example, is a technology that could accommodate low-sulfur coal very readily.

Dr. YEAGER. Absolutely.

Mr. BOUCHER. I guess the real concern of the industry is that high-sulfur coal tends to be somewhat cheaper, and if a utility has gone to the expense and the trouble of instituting a clean coal technology which can burn high-sulfur coal consistently with whatever emission requirements are in effect that the natural economic choice for that utility is then going to be to buy high-sulfur coal, and so the institution of the technology, the utilization of that in a particular utility, almost necessarily leads to a further decision to use high-sulfur coal as opposed to low-sulfur coal.

Dr. YEAGER. Well, I guess I would turn that comment around in that the intention of the Clean Coal Technology Program, as I would view it at least, is to provide an array of options which will certainly include coal switching, and I think that the objective that we would have and I believe the Congress, by and large, has is to assure that we have the lowest-cost options available to the market, and indeed there will be cases where low-sulfur coal, if the regulations permit, will be the choice. I see no reason why there will not be an equilibrium among those choices.

Mr. BOUCHER. On that note, we'll depart from my parochial concern, and I appreciate very much your answers.

Gentlemen, thank you for being with us today. We will leave the record open for additional questions to be submitted to you and for the receipt of your answers.

[Questions and answers for the record follow:]

CLEAN COAL TECHNOLOGY COALITION
1050 Thomas Jefferson Street, N.W. Seventh Floor, Washington, D.C. 20007 (202) 298-1827

Chairman: R.E. Disbrow
President and COO
American Electric Power Service Corp.
Vice Chairman: Paul C. Bailey, Jr.
Governmental Affairs Representative
Southern Company Services, Inc.
Executive Director:
Ben Yamagata

Allied-Signal, Inc.
Allison Gas Turbines/
General Motors
Amax Coal Co.
American Electric Power
Arch Mineral Corp.
Babcock & Wilcox
Baltimore Gas &
Electric Co.
Bethlehem Steel Corp.
Centerior Energy
Central Illinois
Public Service Co.
Combustion Engineering, Inc.
Consolidation Coal Co.
Cyprus Coal Co.
Duke Power Co.
Duquesne Light Co.
Edison Electric Institute
Florida Power Corp./
Electric Fuels Corp.
Florida Power &
Light Co.
General Electric Co.
General Public Utilities, Inc.
Illinois Power Co.
Indianapolis Power & Light
Industrial Fuels Corp.
Island Creek Corp.
Jersey Central Power &
Light Co.
M.W. Kellogg Co.
Madison Gas and Electric Co.
Metropolitan Edison Co.
MHD Development Corp.
National Coal Association
National Lime Association
Northern Indiana Public
Service Co.
Ohio Edison
Oklahoma Gas & Electric Co.
Orange & Rockland Utilities, Inc.
Peabody Holding Company, Inc.
Pennsylvania Electric Co.
Pennsylvania Power &
Light Co.
Pittsburg & Midway Coal
Mining Co.
Public Service Company
of Indiana
Sargent & Lundy
SOMED, University of Alabama
Southern Company Services
Southern Illinois University
Texaco, Inc.
The Commonwealth of Kentucky
The State of Illinois
The State of Indiana
The State of Minnesota
The State of Ohio
The State of West Virginia
TransAlta Utilities Corp.
Union Electric Co.
United Mine Workers of America
University of Southern Indiana
West Virginia University

April 27, 1988

Honorable Marilyn Lloyd
Chairman
Subcommittee on Energy Research
and Development
2321 Rayburn House Office Building
Washington, D.C. 20515

Attention: Lottie McCaw-Daniels

Dear Chairman Lloyd:

Attached are responses to the three supplemental questions of the Subcommittee posed in your March 22 letter.

I greatly appreciated the opportunity to testify before your subcommittee, and on behalf of the members of the Coalition, I want to express our gratitude for your continuing support and that of your Members.

With best regards,

Sincerely,

Ben Yamagata

Enclosure

Responses to Republican Member Questions
for the Hearing of March 2, 1988 for
BEN YAMAGATA, EXECUTIVE DIRECTOR, CLEAN COAL TECHNOLOGY COALITION

1. What is the rationale for subsidizing the demonstration of "clean coal technologies" at the taxpayers' expense? What analyses exist that prove conclusively that utilities cannot afford to fund these demonstrations out of their own funds?

RESPONSE: Federal financial assistance (in amounts not to exceed 50 percent of project cost) made available to projects intended to demonstrate a clean coal technology will assist in the accelerated commercialization of that technology. The public/private partnership of the clean coal demonstration program is justified, in part, by the public benefits to be derived from the greater use of coal - our most abundant domestic fossil fuel resource -- in a cost-effective and environmentally acceptable manner.

With respect to the question of utility efforts to fund demonstrations with private resources only. I am not aware of any analyses that prove conclusively that utilities will not proceed independent of public funds. I would note, however, that few utilities will likely assume the risks attendant to first-of-a-kind projects. A regulated entity may be required to assure all of the risks of failure, yet obtain none of the rewards for success. In other words, the risks on initial demonstrations far outweigh the rewards.

2. The DOE's press release of February 22, 1988, announcing the competition for $536 million in Federal funds "to demonstrate a new generation of environmentally clean, innovative coal technologies" says that "[t]he department will also consider the recommendation of the Vice President's Regulatory Relief Task Force to give preference to projects in states that treat clean coal technologies the same as pollution control projects of technologies when setting electricity rates." Do you agree with this "reference", and if so, why?

RESPONSE: Since release of the final PON, the Department has clarified that a preference for a project located in a state that treats clean coal technologies the same as pollution control projects would only be given in the instance where two projects were determined to be otherwise equally qualified (i.e., the state preference would be used as a "tie-breaker"). The Coalition believes - and has so informed the Department - that if a preference for the selection of projects located in states for which favorable ratemaking treatment would be afforded a clean coal technology, then such preference should not be limited simply to those states that provide treatment for the proposed clean coal project similar to state treatment of pollution control projects. Any form of favorable regulatory treatment, like accelerated rate amortization or incentive rates should also be considered. To limit the preference to a specific regulatory treatment would seem to defeat the purpose of combining the clean coal program with state-granted regulatory incentives that, together, could operate as significant stimuli for encouraging the conduct of clean coal technology projects.

3. You state in your testimony that "[m]any Coalition questions about program direction and requirements were addressed in the final PON," and that you "anticipate further clarification at the Department's conference in mid-March." What are the areas of additional clarification that you are seeking?

RESPONSE: Members of the Clean Coal Technology Coalition, particularly those members who are technology vendors, have considerable concern about the Department's requirement for repayment (Section 6.4 of the Program Opportunity Notice). There is much confusion regarding the Department's explanation of what is included in the so-called "envelope of technology" that the repayment requirement covers.

Many of our members fear that without a clearer indication of what the "envelope" covers (e.g., a patent), and/or a lowering of the two percent (2%) of gross sales requirement, there will be a repeat of the misunderstandings regarding repayment provisions that plagued the first solicitation and caused considerable criticism of the Department. Further, while vendors do not object to repayment, they believe the 2% of gross sales requirement coupled with the ambiguity of the "envelope" is totally unacceptable. Specifically, given the highly competitive nature of the market for electric generation and emissions control technologies, the vendors believe that 2% of gross sales could well exceed their profit margin. The Coalition has expressed these continuing concerns about the repayment provisions to the Department, and we anticipate further clarification before the May 23 deadline for project proposal submissions.

EPRI
Electric Power
Research Institute

April 28, 1988

Ms. Marilyn Lloyd
Chairman, Subcommittee on Energy
Research and Development
Committee on Science, Space,
and Technology
2321 Rayburn House Office Building
Washington, D.C. 20515

Dear Chairman Lloyd:

Attached are my responses to the questions in your letter of March 22, 1988. These are intended to expand on my testimony of March 2, 1988 to the Subcommittee hearing on Fossil Energy Research and Development.

I appreciate this opportunity to share my perspective on the demonstration of Innovative Clean Coal Technology. I look forward to working with your Subcommittee as it continues its outstanding leadership on issues involving energy research and development and its fundamental importance to our nation's future.

Very truly yours,

Kurt Yeager

Kurt Yeager
Vice President
Coal Combustion Systems

1019 Nineteenth Street, NW, Suite 1000, Washington, DC 20036 Telephone (202) 872-9222
Headquarters: 3412 Hillview Avenue, Post Office Box 10412, Palo Alto, CA 94303 (415) 855-2000

1. **What is the rationale for subsidizing the demonstration of "clean coal technologies" at the taxpayers' expense? What analyses exist that prove conclusively that utilities cannot afford to fund these demonstrations out of their own funds?**

Demonstration represents both the last step in the technical development of a technology and the first step in its formal commercialization. These demonstration projects have large design margins and levels of redundancy to assure reliable operation at first commercial scale. They typically represent the highest cost point in the development cycle since cost must still be secondary to assured reliability even though the scale of facility has reached the commercial threshold.

Thus, even though the technology being demonstrated promises lower cost relative to its competition when commercial maturity is reached, it may not be economically competitive at demonstration. Cost-sharing will be required to offset these first-of-a-kind costs and risks. The justification for federal participation in this cost- and risk-sharing depends on the national benefit of expediting confident demonstration and commercial introduction of Innovative Clean Coal Technology (ICCT). This benefit recognizes the strategic importance of coal and includes strengthening the economy through more productive use of coal, reduced dependence on foreign petroleum, and resolution of the conflicts between coal and the environment. Cost- and risk-sharing and removal of disincentives limiting private investment are two complementary methods of encouraging achievement of these benefits through ICCT. Both should be part of the ICCT policy arsenal.

The issue is not whether regulated utilities can afford to fund demonstrations, but rather that they lack the risk-reward incentives necessary to do so in the regulatory environment under which they operate. As evidence of its commitment, the electric utility industry has invested over $1 billion during the past decade in developing, to the point of demonstration alone, the array of technologies which comprise ICCT. This was largely accomplished as part of the industry's collaboratively funded, joint-venture, R&D program through EPRI. This funding collaboration is possible because it is accepted by the state regulatory commissions as part of each member utility's rate base. Demonstrations, on the other hand, are typically large, individual capital investments made by an individual utility. These must be justified on their commercial merit to both the regulatory commission and the utility stockholders. They are generally not included in the rate base until commercial need is justified and the cost does not exceed the evaluated least cost alternative. This decision may not even be made until after the utility invests in and constructs the facility, thus leaving its stockholders potentially "holding the bag." In addition, since the regulated utility and its stockholders will not share in the profits that may ultimately accrue from accepting the risks of a new technology, it lacks incentive to bear these additional risks and costs irrespective of enthusiasm for the technology's ultimate merits. Ongoing ICCT demonstrations, such as atmospheric fluidized bed combustion (AFBC) and integrated gasification combined cycle (IGCC) have been successfully implemented by the electric utility industry because manufacturers and governments have recognized and shared these additional, first-of-a-kind, demonstration costs with the host utility.

2. **The DOE's press release of February 22, 1988, announcing the competition for $536 million in Federal funds "to demonstrate a new generation of environmentally clean, innovative coal technologies" says tht "the department will also consider the recommendation of the Vice President's Regulatory Relief Task Force to give preference to projects in states that treat clean coal technologies the same as pollution control projects or technologies when setting electricity rates." Do you agree that with this "preference," and if so, why?**

   Yes, I agree with this preference because it recognizes the circumstances outlined above which limit the practical ability of the electric utility industry to implement ICCT demonstrations. It is a clear message from the federal government for the states to recognize the national strategic value of ICCT and the need to remove disincentives which constrain its commercial demonstration and subsequent availability in the market. By and large these disincentives are controlled at the state level with limited federal leverage except through cost-sharing guidelines.

3. **What other nations are pursuing a program similar to the U.S.' Clean Coal Technology Program? What level of government funding is being provided in each of these nations?**

   Most of our international competitors for the ICCT market, particularly Japan and West Germany have had national initiatives for ICCT demonstration underway for some time. This has given them a substantial lead in commercializing ICCT technologies for the world market which, in many cases, were originally developed in the

U.S. These involve not only cost- and-risk-sharing but a sustained and consistent national policy with goals and incentives agreed to and shared by private and public interests alike. This consistency has meant that our competitors have achieved a much greater "bang for their buck" in ICCT than the U.S. where sustained and consistent policy has not been established. The policies of our competitors recognize the strategic importance of ICCT not only at the national level, but also for an international market exceeding $50 billion/year by 2000. ICCT represents a microcosm of the larger issues facing U.S. technology policy. Our competition maintains the federal/private joint venture approach through demonstration and commercial introduction. At this point, potentially superior U.S. initiatives typically fail because they lack similar reinforcement.

Japan, for example, through the Ministry for International Trade and Industry (MITI), has subsidized the costs of demonstrating advanced SO_2 AND NO_x control technology through grants to electric utility/manufacturer teams. Typically, several such demonstrations for each of several competing technologies and teams are subsidized leading to the best solutions for both domestic and future foreign markets.

In order to more cost effectively implement its new SO_2 and NO_x emission standards, W. Germany has subsidized a large number of SO_2 and NO_x pilot and demonstration facilities with the electric utility industry. Over 50 such NO_x control facilities alone have been installed under this program since 1985. This initiative is administered primarily at the state level with federal oversight and policy guidance. This government support has enabled industry to accelerate installation of mandated emission control equipment by at least five years.

Again, it is less the absolute amount of money spent by other governments than the longer term consistancy of their policies which distinguish them from the U.S. Our tendency to spend heavily in a crisis mode and then withdraw support based on short term political considerations means that resources are wasted and our goals diffused. The ICCT demonstration initiative is an opportunity to reverse that pattern by establishing a national joint-venture effort with consistent, strategic policies and stable resources from both the public and private sector.

Mr. BOUCHER. That concludes today's hearing. This Subcommittee will meet tomorrow morning at 9:30 in this room.

[Whereupon, at 11:10 a.m., the Subcommittee was adjourned.]

1989 DEPARTMENT OF ENERGY AUTHORIZATION

THURSDAY, MARCH 3, 1988

House of Representatives,
Committee on Science, Space, and Technology,
Subcommittee on Energy Research and Development,
Washington, DC.

The Subcommittee met, pursuant to notice, at 9:30 a.m., in Room 2318, Rayburn House Office Building, Hon. Rick Boucher [presiding].

Staff Present: Dr. Harlan Watson; Nancy Jeffery; and Kitty Rising.

OPENING STATEMENT OF HON. RICK BOUCHER, THE U.S. REPRESENTATIVE IN CONGRESS FROM THE NINTH DISTRICT OF VIRGINIA

Mr. Boucher. Good morning. This hearing will come to order. Today we are continuing our Department of Energy Fiscal Year 1989 Budget Authorization Hearings for Fossil Research and Development programs. Today we will be receiving testimony from outside witnesses who are most knowledgeable about and interested in fossil R&D activities.

I want to repeat the concerns that were stated yesterday by a number of Members of this panel about the severely reduced level of funding that is recommended by the Department to continue this important research and development during the course of the coming fiscal year.

The lack of funding continuity has in the past, impeded the progress of many programs. I sincerely hope that during this cycle Congress can provide some funding certainty for priority activities.

We have a large number of witnesses who will be testifying today. In fact, we have four panels, so I am going to ask each of the witnesses to please summarize his or her prepared statement in five minutes. Without objection, we will make a part of our record the prepared statement of all of the witnesses.

Before introducing our first panel, I would like to recognize for an opening statement, the Ranking Member of the Subcommittee, Sid Morrison of Washington.

OPENING STATEMENT OF HON. SID MORRISON, RANKING REPUBLICAN MEMBER, SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT

Mr. MORRISON. Thank you, Mr. Chairman. I will be very, very brief. This is a continuation. I think in this whole area of fossil energy, Mr. Chairman, we can note with some pride, the cooperation that we have seen between the Federal agencies, the research facilities around the country and private enterprise.

So we look forward to hearing from two of those segments today and we trust that before we get through with this that we will be better able to find the bottom line that works for the whole country.

Thank you, Mr. Chairman.

Mr. BOUCHER. The gentleman from Texas.

Mr. SMITH of Texas. Please go on. Although it is not here yet, I would like permission to enter for the record an opening statement.

Mr. BOUCHER. Without objection, that is so ordered. Also, I ask unanimous consent that the Subcommittee permit today's hearings to be recorded and covered by the media and by other persons. Without objection, that is so ordered.

PANEL 1: FUEL CELLS

Our first panel today will discuss fuel cells, and consists of Dr. Martin Gutstein, Executive Director of the Industrial Fuel Cell Association; Mr. Frank Schora, representing the M-C Power Corporation; and, Nathaniel Woodson, representing the Westinghouse Electric Corporation.

I would ask each of you to give your statement in turn, and as I indicated earlier, the Subcommittee would greatly appreciate a summary of the prepared statements the full text of which will be made a part of the record.

Mr. Gutstein, we will be happy to hear from you.

STATEMENT OF MARTIN GUTSTEIN, EXECUTIVE DIRECTOR, FUEL CELL ASSOCIATION, WASHINGTON, DC

Mr. GUTSTEIN. Thank you, Mr. Chairman. Mr. Chairman and Members of the Subcommittee, my name is Martin Gutstein. I am the Executive Director of the Fuel Cell Association, FCA, and I am substituting for Mr. Frank Spillers, President of the Association, who is unable to attend today.

The Fuel Cell Association is a not-for-profit organization, comprising both developers and potential users of fuel cell systems. We have approximately 30 corporate members from a wide variety of industries and about 25 associate or individual members. Our objective is to support the development and commercialization of fuel cells in all applications.

The members of the Association believe that it is vital that our national energy policies be proactive rather than reactive. In order to do this, we must set goals and strategies with a Federal fuel cell research and development program that are consistent from year to year and are immune from the dictates of succeeding administrations. They should not be responsive only to the energy crisis of the moment.

In other words, we urge Congress and the Administration to provide support for long-term, high-payoff fuel cell R&D primarily focused on advanced technologies, the level of which is consistent with programmatic needs and technical progress.

Unfortunately, we view the Administration's proposed fiscal year 1989 fuel cell budget, an 80 percent reduction from last year's level, as failing to adhere to this standard. Indeed, these cuts are not in the best interest of the future of this country. FCA has not had time to prepare its own fiscal year 1989 budget recommendations. We would appreciate the opportunity to submit these to the Subcommittee as an addendum in time for your budget deliberations.

Worldwide competition in fuel cell systems is rapidly becoming a reality. Overseas companies are being heavily supported by their governments and commercialization is their prime objective. The Moonlight project in Japan for molten carbonate fuel cells is a dramatic example of a proactive policy in its approach to new energy supplies. Similar activities in other countries in support of fuel cells can also be cited. Be assured the United States is the market of choice for these suppliers.

Congress must continue American leadership and competitiveness in these technologies.

I would like to turn now to another issue, namely the performance of DOE's fossil energy program as it impacts the development of fuel cells. In June of last year, DOE announced under a Headquarters program policy directive that it would not make any awards under its solicitation for a coal-gas fuel cell. In dropping the solicitation after substantial efforts and expense from the private sector and a significant waste of public funds, the action caused great uncertainty among organizations committed to molten carbonate fuel cells as well among potential users.

This solicitation was originally mandated by the U. S. Congress in fiscal year 1986. Its aim was to establish a multi-year R&D program that eliminated delays and uncertainties associated with yearly contracting. In other words, to eliminate the procurement practices that DOE has managed to foster.

Similarly, a solicitation issued in 1987 by DOE for development of advanced fuel cell concepts was withdrawn, only to be reissued with a change in technical emphasis, but after bidders had spent time responding to the original. Likewise, the Fossil Office's current plans to integrate some fuel cell programs into the Clean Coal Initiative will confuse the funding situation further.

The actions of the DOE Fossil Program Office have delayed fuel cell development in this country, widened the gap with overseas competitors, and demonstrated the Fossil Office's disregard of the needs of industry. As a consequence, we recommend that Congress specify to DOE and OMB again the need to implement separate, well-defined, multi-year programs for fuel cells and for these agencies to anticipate funding the programs at consistent, effective levels.

Important applications for fuel cells are to be found not only in the electric and gas utilities and in integration with coal derived fuel processing, but in other industries as well. These include chemical and petrochemical processing, automotive and other transportation applications, off-grid power plants for export, and commercial and residential uses.

If fuel cells can penetrate one or more of these markets, they will make major impacts on this nation, and indeed, the world. Fuel cells for these applications use such fuels as natural gas, methanol, waste industrial gases, biofuels, et cetera. They are being addressed by DOE at inadequate, even meager levels.

We therefore urge Congress to recognize the need for additional fuel cell R&D especially within the DOE conservation and renewable programs where such research properly belongs.

FCA firmly believes that fuel cells can play a major role in the Nation's energy and environmental well being. We are confident that with a proactive national policy and appropriate Federal R&D funding levels to ensure U.S. leadership, the goal can and will be met.

[The prepared statement of Mr. Gutstein follows:]

Fuel Cell Association
Suite 300
1627 K Street, NW
Washington, DC 20006

STATEMENT OF

MARTIN GUTSTEIN

EXECUTIVE DIRECTOR OF THE FUEL CELL ASSOCIATION

Before the

SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT

COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY

U.S. HOUSE OF REPRESENTATIVES

-March 3, 1988-

STATEMENT OF

MARTIN GUTSTEIN

EXECUTIVE DIRECTOR OF THE FUEL CELL ASSOCIATION

Before the

SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT

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U.S. HOUSE OF REPRESENTATIVES

-March 3, 1988-

The Fuel Cell Association is a not-for-profit organization comprising both developers and potential users of fuel cell systems. We have approximately 30 Corporate Members from a wide variety of industries and about 25 Associate or individual members. Our objective is to support the development and commercialization of fuel cells in all applications. During the past year, FCA increased its membership by about 40 percent. We think this growth is indicative of continued expanding interest in fuel cells in this country and abroad and of a desire by industry to work together to achieve the objectives I cited above.

The members of the Association believe that it is vital that our national energy policies be PROACTIvE, rather than reactive. In order to do this, we must set goals and strategies for the Federal fuel cell research and development program that are consistent from year-to-year and are immune from the dictates of succeeding administrations. They should not be responsive only to the energy crisis of the moment. In other words, we urge Congress and the Administration to provide support for long-term, high pay-off fuel cell R&D primarily focused on advanced technologies, the level of which is consistent with programmatic needs and technical progress. Unfortunately, we view the Administration's proposed FY1989 fuel cell budget, an 80 percent reduction from last year's level, as failing to adhere to this standard. Indeed, these cuts are NOT in the best interests of the future of this country. FCA has not had time to prepare its own FY1989 budget recommendations; we would appreciate the opportunity to submit these to the

Subcommittee as an addendum, in time for your budget deliberations.

World-wide competition in fuel cell systems is rapidly becoming a reality; overseas companies are being heavily supported by their governments and commercialization is their prime objective. The "Moonlight" Project in Japan for molten carbonate fuel cells is a dramatic example of a PROACTIVE policy in its approach to new energy supplies. Similar activities in other countries in support of fuel cells can be also be cited. Be assured, the United States is the market of choice for these suppliers. Congress must continue American leadership and competitiveness in these technologies.

I would like to turn now to another issue, namely, the performance of DOE's Fossil Energy program as it impacts the development of fuel cells. In June of last year, DOE announced, under a Headquarters Program Policy Directive, that it would not make any awards under its solicitation for a coal gas-fueled fuel cell. In dropping the solicitation, after substantial efforts and expense from the private sector and a significant waste of public funds, the action caused great uncertainty among organizations committed to molten carbonate fuel cells as well as among potential users. This solicitation was originally mandated by the U.S. Congress in fiscal year 1986; its aim was to establish a multi-year R&D program that eliminated delays and uncertainties associated with yearly contracting, in other words, to eliminate the procurement practices DOE has managed to foster.

Similarly, a solicitation issued in 1987 by DOE for development of advanced fuel cell concepts was withdrawn, only to be reissued with a change in technical emphasis, but after bidders had spent time responding to the original. Likewise, the Fossil Office's current plans to integrate some fuel cell programs into the Clean Coal Initiative will confuse the funding situation further.

The actions of the DOE Fossil Program Office have delayed fuel cell development in this country, widened the gap with overseas competitors, and demonstrated the Fossil Office's disregard of the needs of industry. As a consequence of these inept and arbitrary practices, **we recommend that Congress specify to DOE and OMB again the need to implement separate, well-defined, multi-year programs for fuel cells and for these Agencies to anticipate funding the programs at consistent, effective levels.** I will make an additional recommendation concerning DOE's role in fuel cells shortly.

Important applications for fuel cells are to be found not only in the electric and gas utilities and in integration with coal-derived fuels processing, but in other industries as well. These include: chemical and petrochemical processing; automotive and other transportation applications; off-grid powerplants for export; and commercial and residential uses. If fuel cells can penetrate one or more of these markets, they will make major impacts on this nation and, indeed, the world. Fuel cells for these applications use such fuels as natural gas, methanol, waste industrial gases, biofuels, etc.; they are being addressed by DOE at inadequate, even meager levels. **We therefore urge Congress to recognize the need for additional fuel cell R&D, especially, within the DOE-Conservation and Renewable programs, where such research properly belongs.**

I would like now to turn the Subcommittee's attention to the activities of the Fuel Cell Association.

During the past year, the Corporate Members of the Association voted to change its name from the "Industrial Fuel Cell Association" to the "Fuel Cell Association." This action reflected the desire of the members to support the full spectrum of fuel cell markets and applications, including the utility, industrial, transportation and commercial-residential uses. In spite of limited resources, the officers, directors, and members are striving to make FCA an active force in the commercialization of fuel cells.

For example, this year, we have initiated a project to explore the potential for FCA to "broker" the testing of fuel cells at industrial sites. About nine companies have expressed willingness to discuss this opportunity with us. We have begun the preparation of informational materials describing the technical status and benefits of fuel cell systems and we are organizing sessions at conferences on a variety of critical issues affecting the fuel cell community. Although we originally invited DOE's support and still welcome it, FCA is proceeding with these initiatives without that agency's involvement. We hope to make our activities another example of industry filling a leadership void. We intend to keep this Subcommittee informed of our progress in the coming months.

FCA firmly believes that fuel cells can play a major role in the nation's energy and environmental well-being. Moreover, in our opinion, the Library of Congress study, entitled "Fuel Cells for Electric Power Production: Future Potential, Federal Role and Policy Options" by Fred Sissine, dated January 17, 1985, is an excellent starting point for mapping out a path toward this goal. We are confident that with a proactive national policy and appropriate Federal R&D funding levels to ensure U.S. leadership, the goal can and will be met.

Mr. **Boucher**. Thank you very much, Mr. Gutstein. Dr. Schora, we will be happy to hear from you.

STATEMENT OF DR. FRANK C. SCHORA, PRESIDENT, M-C POWER CORP., CHICAGO, IL

Dr. **Schora**. Thank you, Mr. Chairman and members of the Subcommittee. My name is Frank Schora. I am President of the M-C Power Corporation, an Illinois-based company formed last year to scale-up, demonstrate and eventually commercialize the IMHEX molten carbonate fuel cell technology.

This technology will lower the cost of electrical power generation, significantly increase the fuel to electric efficiency and operate at very low noise levels, all without the creation of air pollutants. Either natural gas or coal are suitable fuels; natural gas for small on-site applications, and coal for larger utility applications.

Molten carbonate fuel cell energy conversion technology has been under active development in the laboratories of IGT for more than 25 years. From these efforts has evolved the IMHEX concept, which is an innovative, internally-manifolded approach to molten carbonate stacks.

We will employ a novel manufacturing concept to fabricate these separator plates at greatly reduced costs which should make this system very attractive for power generation. The IMHEX fuel cell, because of its operating temperature, does not require costly platinum catalyst in the electrodes as do the phosphoric acid type cells operating at lower temperatures.

Instead, the IMHEX fuel cell can use much less expensive nickel electrodes and, in the future, possibly copper. Because of its elevated temperature of operation, by-product heat is produced at high enough temperatures to enable practical application for additional electrical power generation or for commercial and industrial cogeneration.

With uncertainties in future fuel supply availability and cost, it is important to complete the development of high-efficiency energy conversion technologies as quickly as possible so that we can maximize the use of coal as a non-polluting fuel. I believe a level of Federal funding should be established which will enable a continuous advance of the technology toward commercial status.

M-C Power is working on a team basis with IGT, the technology developer, and a major U.S. engineering company with extensive experience in the power-generating business to scale up the IGT internal manifold concept. This is under a two-year cost shared DOE contract. Under this contract, we will design a coal-fueled MCFC electric-power generating plan based on this concept.

$8.5 million is needed in fiscal year 1989 to fulfill the obligation for this R&D effort to be performed under the DOE contract. This amount will provide increased funding of $1 million for system studies; $1 million for stack design; and $0.5 million for stack thermal and stress analyses to more adequately support these areas in the IMHEX development effort.

We understand that DOE intends to issue a program research and development announcement in fiscal year 1989 for molten carbonate fuel cell prototype stack development. The M-C Power team fully expects to be a strong and responsive domestic competitor should that solicitation occur. Such a solicitation would provide much the same economical and technical validation for molten carbonate cells as is being provided for coal-using technologies under the existing innovative Clean Coal Technology Program.

As President of M-C Power Corporation which has as its specific corporate objective the scale-up and commercialization of this exciting molten carbonate fuel concept, I believe we can attain this objective in the next five to seven years given adequate funding. That such systems are needed in the future in the United States is without question.

By the mid to late 1990's conservatively, the domestic market for molten carbonate fuel cells could exceed 400 megawatts per year for specialized application; 3,000 megawatts for dispersed power generation. Based on a long study of the various options available for future electrical power generation, I strongly believe that the molten carbonate system as being developed by the M-C Power team will be one of the systems to achieve wide acceptance both for the smaller on-site systems and for the larger utility operated systems.

I thank you Mr. Chairman, for the opportunity to appear here and would be happy to answer any questions.

[The prepared statement of Dr. Schora follows:]

STATEMENT BY FRANK C. SCHORA
PRESIDENT, M-C POWER CORPORATION
HOUSE COMMITTEE ON SPACE, SCIENCE AND TECHNOLOGY
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT

March 3, 1988

Madame Chairman and Members of the Subcommittee:

My name is Frank Schora, I am President of M-C Power Corporation, a Chicago based company formed last year to scale-up, demonstrate, and eventually commercialize the IMHEX Molten Carbonate Fuel Cell technology. This technology will lower the cost of electrical power generation, significantly increase the fuel to electric efficiency and operate at very low noise levels, all without the creation of air pollutants. Either natural gas or coal are suitable fuels, natural gas for small on-site applications and coal for larger utility applications.

Molten carbonate fuel cell energy conversion technology has been under active development in the laboratories of the Institute of Gas Technology for more than 25 years. From these efforts has evolved the IMHEX concept, which is an innovative internally manifolded approach to MCFC stacks, combining the functions of the separator plate and current collector/gas distributing components into a single piece. This metallic separator plate is one of the critical components of the cell stack, and can be one of the most costly. We will employ a novel manufacturing concept to fabricate these separator plates at greatly reduced costs, which should further make this system very attractive for power generation. The IMHEX fuel cell, because of its operating temperature, does not require costly platinum catalyst in the electrodes as do the phosphoric acid type cells operating at lower temperatures. Instead, the IMHEX fuel cell can use much less expensive nickel electrodes and, in the future, possibly copper. Because of its elevated temperature of operation, by-product heat is produced at high enough temperatures to enable practical application for additional electric power generation, or for commercial and industrial cogeneration.

With uncertainties in future fuel supply availability, and cost, it is important to complete the development of high efficiency energy conversion technologies as quickly as possible so we can maximize the use of coal as a non-polluting fuel. I believe a level of federal funding should be established which will enable a continuous advance of the technology toward commercial status.

M-C Power is working on a team basis with IGT (the technology developer), and a major U.S. engineering company with extensive experience in the power generating business, to scale-up the IGT internally manifolded MCFC technology under a two year cost shared DOE contract. Under this contract we will: - design a coal-fueled MCFC electric power generating plant based on the IMHEX concept.

- assess the cost of electricity from the MCFC plant against alternative electricity generating methods
- Optimize the design and initiate scale-up of an IMHEX stack
- fabricate IMHEX stack components
- test MCFC stacks embodying the IMHEX concept

$8.5MM is needed in FY'89 to fulfill the obligation for the R&D effort to be performed under the DOE contract. This amount will provide increased funding for system studies ($1.0M) stack design ($1.0M) and stack thermal and stress analysis ($0.5) to more adequately support these areas in the IMHEX development effort.

We understand that DOE intends to issue a Program Research Development Announcement in FY'89 for Molten Carbonate Fuel Cell Prototype Stack Development. The M-C Power team fully expects to be a strong and responsible domestic competitor should that solicitation occur. Such a solicitation would provide much the same economical and technical validation for MCFC as is being provided for coal-using technologies under the existing Innovative Clean Coal Technology program.

As President of M-C Power Corporation which has as its specific corporate objective the scale-up and commercialization of this exciting molten carbonate fuel cell concept, I believe we can attain this objective in the next 5-7 years given adequate funding. That such systems are needed in the future in the United States is without question. By the mid to late nineties, conservatively, the domestic market for MCFC could exceed 400 MW per year for specialized applications, 3,000 MW per year for dispersed power generation, and at least 25% of annual capacity additions to utility base-load electric generation. Based on a long study of the various options available for future electrical power generation I strongly believe the MCFC system as being developed by the IGT M-C Power team will be one of the systems to achieve wide acceptance both for smaller on-site systems and for larger utility operated systems.

I thank you for the opportunity to appear before this Subcommittee and I will be happy to answer any questions.

Mr. BOUCHER. Thank you, sir. We appreciate your testimony. Mr. Woodson, we will be happy to hear from you.

STATEMENT OF NATHANIEL D. WOODSON, GENERAL MANAGER, ENERGY SYSTEMS TECHNOLOGY DIVISIONS, WESTINGHOUSE ELECTRIC CORP., PITTSBURGH, PA

Mr. WOODSON. Thank you, Mr. Chairman. I am Nat Woodson, General Manager of the Westinghouse Energy Systems Technology Divisions. In concert with the efforts of the Westinghouse Research and Development Center, my organization is responsible for the company's efforts in fossil energy development in commercial programs.

Our engineers and scientists have experience in such areas as fuel cells, coal gasification, hot gas stream cleanup, MHD, precombustion coal cleaning, fluidized bed combustion, advanced coal fuel gas turbine systems, coal bed methane utilization, waste coal utilization, advanced coal-fired locomotives, all coupled with innovative state-of-the-art control systems with artificial intelligence monitors to enhance the performance of these technologies.

Westinghouse indeed recognizes the importance of fossil energy in solving the Nation's energy puzzle. Our challenge is to ensure that all developing technologies receive a detailed and reasoned evaluation and a commitment for the demonstration funding necessary for those technologies which show the greatest promise.

For purposes of my discussion today, I will be concentrating on fuel cells. I do this for two important reasons. They represent a very promising technology with a projected market niche where significant progress has been made because of public and private support. There is also a technology and danger of premature abandonment without continued support for early demonstration.

Westinghouse's fuel cell interests lie in technologies of air-cooled phosphoric acid and tubular solid oxide. Phosphoric acid is the near-term, relatively lower temperature process aimed at multi-megawatt applications, while the solid oxide is a longer-range, high-temperature unit capable of both small on-site as well as larger multi-megawatt applications. These will be compatible with coal gas as a fuel, and they are environmentally benign.

To ensure compatibility of the fuel cell technologies with coal gas, it is essential that near-term demonstrations be initiated. One approach would be to utilize a slip stream of coal gas from a gasification combined cycle plant being developed under the Clean Coal Program. This appears to be a relatively low-cost, yet important, proof of compatibility.

A demonstration project will be required to maintain a viable program and build user confidence in the technologies. We have developed a 1.5-megawatt demonstration plant that is a composite of commercial-sized systems and components.

Drastic changes in the electric power generation market brought about by the introduction of PURPA has made it difficult for utilities to predict future generation needs. In addition, tight utility regulation reduces their willingness to invest in the future. This presents us with a problem of finding major customers willing to support demonstrations in an early stage.

We are taking every step possible to solve the difficult funding problems for this demonstration plant, including the willingness to develop equity partnerships and offer exclusive marketing rights to selected firms. Without support for a demonstration program, we face the real possibility of moving our nation's technological advantage in this important program to other countries.

At the Westinghouse Research and Development Center, our engineers and scientists are working on a multi-decade, multi-million dollar program on solid oxide high-temperature fuel cell technologies. The primary objective is design, fabrication and testing of a generator by the first quarter of 1989.

We have contracts with the Gas Research Institute and additional support from a consortium of gas utilities in Japan, and the cooperation of the new Energy Development Organization. The DOE and Gas Research Institute programs, along with utility-sponsored programs, are integral parts of our commercialization plan.

Westinghouse technology for field test units and their success is another vital link in the continuing commercialization plan. Presently, Westinghouse is investing in a new pre-pilot manufacturing facility, capable of producing 10,000 solid oxide fuel cells per year. The pre-pilot program provides the opportunity to move the technology from the laboratory to the manufacturing environment.

The next units in the multi-hundred-kilowatt size will provide Westinghouse with the technology that can serve cogeneration markets in the early 1990's. Continued program progress will depend on continuing private interest and support and long-term Government commitment to support technology development and demonstration.

As I hope you can see, significant progress has been made in our fuel cell programs. Sitting here today, the phosphoric acid is ready for a large, 1.5-megawatt demonstration program, a successful wrap-up to previously funded R&D programs. Solid oxides are ready for further development in the areas of durability, manufacturing and the direct utilization of gas to hydrogen processes.

Both Congress and Westinghouse have invested heavily in these technologies, and we stand on the verge of ensuring the United States with competitive control. However, the future is clouded with uncertainty. We are also faced with the harsh reality of a new competitive pressures from abroad. Our characteristics of some of our formidable overseas competitors is the willingness of their governments to participate in the whole development process and not limit their role to research and development.

Without a policy framework that fosters a Government-industry partnership through pre-commercialization, these factors will continue to impact both Government and industry support for technology development and results in promising technologies migrating elsewhere.

Thank you, Mr. Chairman.

[The prepared statement of Mr. Woodson follows:]

TESTIMONY BY

NATHANIEL D. WOODSON

GENERAL MANAGER

ENERGY SYSTEMS TECHNOLOGY DIVISIONS

WESTINGHOUSE ELECTRIC CORPORATION

Before the

Subcommittee on Energy Research and Development

U. S. House of Representatives

Committee on Science, Space and Technology

March 3, 1988

NATHANIEL D. WOODSON

Nathaniel D. Woodson is General Manager of Westinghouse's Energy Systems Technology Divisions, an organization which integrates the full range of Westinghouse technologies, products, project and commercial management skills for power generation projects. The organization also is involved with alternate energy technologies. Mr. Woodson received a bachelor's degree in mechanical engineering from Yale University, a master's degree in nuclear engineering from Massachusetts Institute of Technology, and a master's degree in business administration from the University of Pittsburgh. He also has completed the Advanced Management Program at the Harvard University Business School.

Madame Chairperson, Members of the Committee, I am Nat Woodson, General Manager of Westinghouse's Energy Systems Technology Divisions. In concert with the efforts at the Westinghouse Research and Development Center, my organizations are responsible for the company's efforts in fossil energy development programs. I appreciate this opportunity to report on the progress of our activities and to share with you my views on what will be needed in the years ahead to achieve the broad national success that continued pursuit of fossil energy technologies can bring.

BACKGROUND

Since World War II, scientific achievement in the United States has often outpaced research and discovery elsewhere in the world. American investigators have won a major share of Nobel Prizes, and have led their colleagues in such fields as physics, biology, medicine, chemistry and computer science. This preeminence in research and development is a direct outgrowth of an active partnership between industry and government. Look no further than computer technology and solid state electronics for evidence that the synergism between public and private research and development over nearly 40 years has yielded major benefits. It is with the thought of strengthening that partnership that I have come today, because I firmly believe that our nation's future as a world leader in science and technology depends on it.

Westinghouse is no stranger to fossil energy technologies. In addition to serving as a major utility supplier for generation systems and components, we have taken an active role in both public and privately funded programs aimed at the development and evaluation of fossil and alternate energy technologies.

Our engineers and scientists have experience in such areas as coal gasification, hot gas stream cleanup, fluidized bed combustion, magnetohydrodynamics (MHD), pre-combustion coal cleaning, coal bed methane utilization, waste coal utilization, and advanced coal-fired locomotives.

Westinghouse recognizes the importance of fossil energy in solving the nation's energy puzzle. We are excited about our participation in the clean, efficient, and economical use of our domestic fossil energy resources.

I'd like to share with you some of our accomplishments and visions in a number of promising fossil technologies including fuel cells, MHD, advanced coal locomotives, fluidized bed combusion, coal gasification, coal bed methane and cogeneration systems, advanced coal fueled gas turbine systems, hot gas cleaning and coal cleaning.

FUEL CELL PROGRAMS

Westinghouse's fuel cell interests lie in the technologies of air-cooled phosphoric acid and tubular solid oxide. We are developing fuel cell technologies which will be compatible with coal gas as a fuel. These noncombusting power generators are environmentally benign. Their relatively small sizes (50 KW to multimegawatts) enhance the match of generating capacity with load growth. In addition, they provide an ideal source of decentralized power whereby the source can be closely coupled with the load. This minimizes transmission and distribution equipment and associated losses.

The Westinghouse fuel cell technologies are adaptable to various clean coal options including dispersed operation from a coal gas pipeline, integrated operation utilizing commercial unpressurized fixed-bed gasification and integrated operation using advanced coal gasification processes, including moving bed, entrained bed, or fluidized bed gasifiers.

To insure compatibility of the fuel cell technologies with coal gas, it is extremely important that near-term demonstrations be initiated. One approach would be to utilize a slip stream of coal gas from an Integrated Gasification Combined Cycle (IGCC) plant being developed under the Clean Coal Program. This appears to be a relatively low cost, yet vitally important, proof of compatibility between a coal-derived fuel and a fuel cell plant.

Phosphoric Acid Fuel Cells

The technical progress on our phosphoric acid fuel cell program has been outstanding and the highly reliable Westinghouse pressurized air-cooled design is particularly well suited for the emerging distributed market. Westinghouse has assembled and tested 100 kW fuel cell stacks and during the next four years, with continued support from Congress, we will design, develop, and test 375 kW fuel cell modules which are the fundamental building blocks for the larger plants.

A multimegawatt demonstration project will be required to maintain a viable program and build user confidence in the technology. Westinghouse has developed a 1.5 MW demonstration plant that is a composite of commercial size 7.5 MW systems and components. This unique approach represents the most cost effective way to demonstrate both the fuel cells and the total plant.

Drastic changes in the electric power generation market brought about by the introduction of PURPA has made it difficult for utilities to predict future generating needs. In addition, tight utility regulation in the U. S. reduces their willingness to invest in and technology development for new power generation. This presents us with the problem of finding major customers willing to support demonstrations and provide an early market for premium priced plants. Although we see the potential for billion dollar markets worldwide, hard data is difficult to obtain during this period of transition. This presents U. S. industry with the problem of making investment decisions at a time when the risks are undefinable.

Westinghouse is taking every step possible to solve the difficult funding problems for this demonstration plant including a willingness to develop equity partnerships and offer exclusive marketing rights to selected firms. In spite of these efforts, the lack of market definition at this time is making private sector investment difficult to obtain. Without support for a demonstration program we face the very real possibility of losing our nation's technological advantage in this important program.

Solid Oxide Fuel Cells

We are also working on a multi-million dollar government-industry program to commercialize solid oxide fuel cell (SOFC) technology in the 1990's.

For more than two decades, Westinghouse has been developing the materials and establishing the processes that will be necessary to commercialize the SOFC technology. A Westinghouse and the DOE joint program, begun in 1980, is focusing on utilizing the SOFC technology with coal-derived fuels. The primary objective of the present phase is the design, fabrication, and testing of a multikilowatt SOFC generator by the first quarter of 1989.

Westinghouse is also under contract to the Gas Research Institute (GRI) to develop SOFC technology for use with natural gas-fueled systems. This contract has the primary objective of developing the capability to introduce natural gas directly into the solid oxide fuel cell generator without the need for a chemical processing plant.

This program was recently amended to study applications and markets, and to develop conceptual designs and cost estimates for onsite cogeneration applications in the power range of 25 kW to several megawatts. This effort is being sponsored by a consortium of gas utilities in Japan in cooperation with the New Energy Development Organization. The DOE and GRI programs, along with several utility sponsored programs, are integral parts of the Westinghouse Commercialization Plan for the SOFC technology.

The Tennessee Valley Authority (TVA) purchased the first Westinghouse SOFC Generator System delivered to a commercial customer and became the first commercial organization to initiate a program to explore the systems aspects of this technology. In November 1987 three 3 kW-size SOFC generators were delivered to Tokyo Gas and Osaka Gas for field testing. These units represent the next scale-up of the Westinghouse technology for field test units and their success is another vital link in the commercialization plan.

Presently Westinghouse is investing in the construction of a new Pre-Pilot manufacturing facility capable of producing 10,000 solid oxide fuel cells per year. The first generators will be produced in this Pittsburgh, Pennsylvania facility during the last quarter of 1988.

The Pre-Pilot Plant provides the opportunity to move the technology from the laboratory to a manufacturing environment and will enable Westinghouse to put in place the processes and quality control programs that will be required to commercialize the technology during the 1990's. In 1989 we will begin producing 25 KW field test units that will make use of the lessons learned in designing, manufacturing and operating multikillowatt size generators.

The next units, in the multi-hundred KW size, will provide Westinghouse with a technology that can serve high value onsite cogeneration markets in the early 1990's. From here, we plan to proceed with a multimegawatt demonstration plant in the late 1990's.

These efforts are part of an aggressive but achievable plan to commercialize SOFC technology. Program progress will depend on continuing private interest and support and a long term government commitment to support technology development and demonstration.

MAGNETOHYDRODYNAMICS (MHD)

Westinghouse has been involved in a variety of projects related to the commercial development of MHD technology. An integral part of Westinghouse's success in MHD contracts has been our systems approach, in which system modeling and analysis computer codes have been developed under Westinghouse funding for the purpose of modeling MHD power plants. In our commercial power plant studies, under the direction of the DOE, Westinghouse used these modeling tools to define design requirements for competitive commercial MHD plants, and performed extensive economic and technical trade-off studies. Westinghouse served as the system integrator for the Component Development and Integration Facility (CDIF), with the responsibility for ensuring engineering and design compatibility between the MHD test train and facility equipment. As a part of this work, Westinghouse designed and built a 3.5 MW inverter. Currently, Westinghouse is teamed with Babcock and Wilcox on seed recovery and regeneration technology development in which we are providing support in the areas of systems engineering and the development of the reduction process equipment.

MHD has been a laboratory and small-scale development effort for 40 years. The necessary next step toward commercialization of MHD requires a large-scale demonstration. Only through a utility-scale application, will the control capabilities, as well as the excellent system efficiency, be demonstrated.

Westinghouse is leading a team which has undertaken the conceptual design of an MHD topping cycle retrofit to an existing coal-fired power plant. The existing steam system would be used as the bottoming cycle to generate electricity from the combustion gas exhausted from the MHD channel.

Our design is based on a unit at Gulf Power's Scholz Plant in Sneads, Florida. We expect that the electrical output of the MHD channel will be 30 MW.

Reducing the conceptual design of a large-scale retrofit to an operating system will involve considerable expense and risk. However, the benefits in air quality and coal utilization should be substantial. The MHD program must identify sources of funds for such a retrofit, if this technology is to be commercialized.

ADVANCED COAL LOCOMOTIVE

With the help of private sector financing, Westinghouse has been investigating the application of coal technology to locomotives as a potential means for decreasing railroad fuel costs and increasing the use of this domestic resource. Westinghouse's concept is an indirect-fired system using a fluidized bed combustor with a combined steam and gas turbine power cycle. This configuration reduces fuel costs compared with current oil-fired diesel systems, while using proven coal combustion technology. Our design requires only low-risk prototype demonstration to become a viable commercial product. We feel that our concept of an indirect-fired advanced coal locomotive prototype program offers the DOE a low risk, low cost alternative for coal locomotive development.

FLUIDIZED BED COMBUSTION

Westinghouse began its research and development work in fluidized bed combustion in 1969 by providing technical support and evaluation of development projects for the Environmental Protection Agency (EPA), the DOE, Electric Power Research Institute (EPRI) as well as a number of private organizations.

As a result of this work we conclude that atmospheric pressure circulating fluidized bed boilers are competitive with conventional pulverized fuel boilers for new, large industrial and small utility installations. It also appears that atmosphere pressure bubbling fluidized bed boilers can be competitive with conventional grate and stoker type boilers for small industrial applications.

Despite large investments by government and industry it is frustrating to note that the bulk of the larger scale fluidized bed boiler installations in the United States today use technology commercialized in Europe. Without a long term strategic approach to development and demonstration programs, it will be difficult for the United States to regain a technology lead in this market.

COAL GASIFICATION

Westinghouse has been involved with the development of coal gasification technology using a pressurized, fluidized bed gasifier in conjunction with hot gas cleanup technology. The work was performed by Kellog-Rust Westinghouse (KRW) Energy Systems, Inc. under the sponsorship of the DOE, Morgantown. Under this program, KRW operated and conducted development testing on a 15-ton-per-day Coal Gasification Process Development Unit, owned by the DOE.

Based upon the success of this coal gasification process, KRW proposed, and was awarded, the Appalachian Project under the Clean Coal Program. This 60 MW Integrated Gasification Combined Cycle project will demonstrate the technology scale-up and economics of this important process.

This effort is a very successful example of the government-industry partnership at work and on behalf of the industry partners I wish to thank this committee, the DOE and Congress as a whole for their long standing support of this important technology. The government has made a significant investment in the gasifier program through development and demonstration with industry now applying the technology on a commercial scale.

COAL BED METHANE AND COGENERATION SYSTEMS

Commercial markets exist for collecting pure methane from coal deposits, prior to mining, and distributing it via pipelines. During mining operations, a lower quality coal bed gas, commonly called gob gas, can be extracted and used for power generation. Two configurations are possible: electric power and cogeneration. In the electric power production option, whereby the gas is burned in gas turbines, the expected efficiency is 22% to 30%. Efficiencies ranging from 35% to 65% are possible through cogeneration. The gas turbine stack heat can be used to dry coal and to pre-heat mine ventilation air. Hot water is another by-product in addition to the production of steam for processing or additional electric power generation.

As an energy systems company which manufactures gas turbines and supplies electrical equipment, Westinghouse is keenly interested in the development of coal bed methane as a power source. In particular, the utilization of gob gas, which is typically vented, presents a unique opportunity to efficiently use domestic energy resources and thereby enhance the energy self-sufficiency of the United States. We have successfully completed a 500 kW demonstration project and seek additional opportunities to commercialize this technology.

ADVANCED COAL FUELED GAS TURBINE SYSTEMS

Westinghouse and the DOE's Morgantown Energy Technology Center are working together to develop a high-efficiency, low cost combustion turbine system that can operate on coal instead of oil or natural gas fuels. The overall objective of the five-year program is to establish the technology required for the commercial application of direct coal fueled slagging combustor-gas turbines to either utility baseload generation or industrial cogeneration . Emissions from these plants are to meet or be lower than EPA's New Source Performance Standards (NSPS) for coal-fired steam generators.

The multi-year program is divided into three key experimental tasks. The first, the design and development of a sub-scale utility type combustor is underway and testing is scheduled to begin in June of this year. The second task, scheduled for 1989, involves further testing with a stationary cascade to study the effect of deposition, erosion and corrosion on gas turbine blades. Finally, the subscale design will be extended to a full size utility combustor and tested to quantify operating conditions with higher, more efficient temperatures and flows. We believe that the technology involved is exceedingly demanding and that the long term objective of burning low cost, untreated utility grade coal cleanly and economically will play a key role in fulfilling our nation's future energy needs. We believe that the technology under development will be successful and that a follow-on demonstration plant will serve as the catalyst for commercialization.

HOT GAS CLEANING

Developing high temperature, high pressure gas cleaning technology that will be required to achieve the low energy cost potential from advanced coal fired energy systems is another area of Westinghouse involvement. Control technology is being developed for particulates, sulfur oxides and trace species such as alkali and nitrogen oxides. The control of emissions is important to meet environmental requirements and to protect process equipment for energy recovery.

Innovative concepts such as the high temperature ceramic cross-flow particulate filter have been successfully tested under contract to the DOE. We have completed tests of this device on gasification and pressurized fluidized bed test facilities. Future development work includes improvements in filter design and fabrication, long term durability testing of the filter and pilot scale tests on gasification and fluidized bed combustion systems.

Other concepts being developed offer the potential for combining particulate, sulfur, nitrogen oxide and alkali control into a single unit operation. This offers significant advantages in emissions control, reduced space requirement and lower energy cost. Hot gas cleaning systems are important components in the development and commercialization of clean coal energy technologies.

COAL CLEANING

Regulations are being implemented to reduce sulfur emissions from coal-fired electricity generating plants and thereby alleviate acid rain. Overall emissions per kilowatt generated can be reduced by sulfur removal and waste heat recovery. A promising coal cleaning process invented by the University of Pittsburgh, uses Liquid Carbon Dioxide (LICADO) at high pressure to physically separate the carbon from ash and pyritic sulfur. The end product is dry coal.

Westinghouse and the University of Pittsburgh are jointly working under a contract with the DOE to demonstrate the technical and economic feasibility of the LICADO process. The two-year project started in October 1987 with funding provided by the DOE Pittsburgh Energy Technology Center (PETC) and directly supports the DOE Clean Coal Research Initiative.

Future work, assuming the feasibility of the process, should concentrate on the design and operation of a 1-ton-per-hour proof-of-concept plant in the 1990 to 1992 time frame. This should then be followed by the design, construction, and operation of a 10-ton-per-hour demonstration plant. Commercial use of such coal cleaning processes will provide the United States with the means to cleanly and efficiently use its abundant domestic coal resources.

Westinghouse is systematically reviewing advanced technologies related to coal utilization in the areas of coal cleaning and coal waste recovery with emphasis on research at universities, laboratories, and small companies. Several technologies that we are currently evaluating are thermoelectric processes in coal-fired plants, conversion of coal bed methane to liquid carbon black fuel, sulfur removal and hydrogen generation in hot gas recovery systems, and fluidized bed fired steam turbine systems to utilize coal waste piles. The goal is to select promising technologies to advance to the prototype development stage.

A VIEW OF THE FUTURE...

All that can be said with any degree of certainty is that the future is uncertain. Numerous factors contribute to the uncertainty: the inability to accurately project new generation capacity; private sector investment constraints driven by short term performance goals; concern over new technology risks; likely slow payoffs; and mounting budget constraints at the federal level.

We are also faced with the harsh reality of new competitive pressures abroad. One characteristic of some of our formidable overseas competitors is the willingness of their governments to participate in the whole development process and not limit their role to research and development. This threatens our technological lead in many key areas and could result in the loss of potential export business.

Without a policy framework that fosters a government-industry partnership through pre-commercialization, these factors will continue to impact both government and industry support for technology development and result in promising technologies falling by the wayside.

Federal support for fundamental inquiry has maintained a pipeline of fresh ideas that may eventually lead to valuable applications while simultaneously covering the risks that individual firms must face in devoting their own resources to new and unproven ventures.

The challenge for Congress is to maintain and enhance a research and development program that ensures promising technologies the necessary funding for development and demonstration. With government support serving as a catalyst to bring these technologies into the marketplace, we can realize the mutual goals of a clean environment and the efficient use of domestic energy resources.

In summary, the programs and accomplishments that I have discussed provide a strong technology base, but they must be carried through to commercial application. The DOE fossil energy group, this committee and Congress have done an excellent job in supporting the development of this technology base. We must continue to work together to ensure that good technologies are not abandoned. A joint government-industry effort focused on a visionary plan and a long-term commitment is required to develop and demonstrate competitive fossil energy technologies for our nation's future.

My staff and I are committed to continue to work with you to build a strong government-industry team dedicated to achieving these goals. It is a unique opportunity we are eager to accept and a challenge we are prepared to meet.

Thank you.

PANEL 1 DISCUSSION

Mr. **Boucher.** Thank you, Mr. Woodson. I have a number of questions which I will propound, and I would ask the panel members, whoever wants to do so to answer them.

First, I would be interested in knowing from you, what you think an appropriate level of funding for the fuel cell program is, and what in your opinion is the appropriate mix between public and private funding to reach that amount should be. Any of you who would care to comment, I would be happy to hear from you.

Mr. **Woodson.** I am willing to lead with my chin.

Mr. **Boucher.** Mr. Woodson.

Mr. **Woodson.** I think we are talking in a range of annual funding of $20 to $25 million, and I would expect that private industry should be able to accommodate 40 percent of that.

Mr. **Boucher.** Any others care to comment?

Mr. **Gutstein.** Our Association would like to come back to you with a more complete answer. We would certainly look to a level of funding from the Federal Government, and possibly a little bit more from the conservation and renewable area.

Dr. **Schora.** Mr. Chairman, likewise, If I could have a day we will get numbers to you as to what we think the funding should be in these various areas.

[The information follows:]

Response to question for Frank Schora on Fuel Cell Budget

As an overall budget recommendation for the fuel cell program, I would suggest the following totals:

Molten Carbonate	
Stack Development	$15.0 million
Supporting Research	3.0 million
Advanced Concepts	
Solid Oxide	$11.5 million
New Concepts	2.0 million
Advanced Research	2.0 million
TOTAL.	$33.5 million

Sincerely,

Frank C. Schora (ke)

Frank C. Schora
President

FCS:lca
Enclosure

Mr. Boucher. That's fine. The record of this hearing will remain open for the receipt of answers to that question and others which either the Chair or other Members of the panel may desire to propound of these witnesses or others who testify here this morning.

I would be interested in knowing what you think the relative expected efficiency of each of the three fuel cell technologies would be. Rank them, if you would, in order of the expected efficiency of the three and the cost savings that would result from their use by the end-users.

Dr. Schora. If I may address that first, Mr. Chairman. The potential of the molten carbonate fuel cell ranges, I feel, anywhere from about 52 percent to 65 percent depending upon the form of the stack, whether it uses internal natural gas or uses a coal based fuel system.

From a power-generating standpoint, again I think this will exhibit very low costs because of the potential of using relatively inexpensive materials such as nickel or copper, and basically using simple fabrication techniques.

The solid oxide systems I think from a thermodynamic standpoint, can't achieve more than about 45 percent overall thermal efficiency—that is fuel to electrical power—without considering extensive bottoming cycles. For the phosphoric system, I think we are also in about the same range of 42 to 25 percent.

As to their costs, not being close to that system, I am not sure what those costs would be. To date, they have been quite high.

Mr. Woodson. If I might add, sir, we see that all of these technologies have exciting efficiencies. As an individual who is personally responsible for managing a large number of technical development programs both in a development and commercialization stage, I feel it is important to point out that one of the things that needs to be carried forward is to move from theoretical calculations to the practicalities of making reliable sources of energy.

One must look at the timing of when those technologies are available to judge the reliability of the educated estimates that are made. I think it is important that in the development of your positions, you consider the time scale and how one makes demonstration programs to prove out the theoretical calculations.

Mr. Boucher. Let's move to that question. When do you anticipate that each of these three technologies will become commercial, and which do you expect to be available for market use first?

Dr. Schora. Again, to address the Committee first, basically the demonstration of phosphoric acid systems is at hand. UTC now, I believe, offers an 11-megawatt system for demonstration by the utility companies. I think there has been some resistance to this possibly because of the uncertainties of the future requirements of the electrical industry, and because it is a size which is not quite appropriate for the utilities and a little bit too big for on-site power generation. That is available.

The molten carbonate system—we feel in five to seven years we will have demonstration units or basically the first commercial units on the market for use. With the solid oxides, there has been extensive work done in this area. However, I think that lags the molten carbonate program possibly by five to 10 years. That's my opinion, sir.

Mr. WOODSON. Again, I would note that phosphoric acid is ready for a one and one-half megawatt demonstration test which will allow the technical experts within the Department of Energy to recognize the proof-of-principle has been established. Our problem has been to engender the support from industrial and utility participants. We have worked to, in fact, imbed this in some of our commercial programs. I can foresee a market evolving in the 1992 to 1995 time period, which I think really dictates that a demonstration program be initiated immediately.

What needs to be done in the other technologies is to move them from technical theory to manufacture of both products that are field grade and field tested. Those need to be done between now and the 1992 time period as they will serve a multitude of markets in the latter 1990's.

Mr. BOUCHER. It would appear from your answer in particular, Mr. Woodson, that the phosphoric acid method is now past the basic research stage and ready for demonstration. Are you suggesting that as a part of this budget we should be providing funds for demonstration projects?

The Department of Energy, as you know, is asking for zero funds for the phosphoric acid fuel cell. Are you in agreement or in disagreement with that, and if in disagreement, what should the monies be devoted to and in what amounts?

Mr. WOODSON. There are, I think in any full-scale research and development program, the needs to bring that development process to a definitive closing point, and that is a demonstration proof of performance. That is the completion of an adequate technology development effort.

I believe that a demonstration program can be pulled together for about $12 to $14 million. I would expect $12 million which could, I believe, finally bring this to a situation where your commercial customers can look at this as proven product and is no longer something that requires joint support of both the public and private sector. The other technologies are not quite at the stage of demonstration programs.

Mr. BOUCHER. You said $12 to $14 million, I believe. Is your recommendation for that amount in public funds or is that the total amount you think would be needed for a demonstration program?

Mr. WOODSON. At this stage, if I could get that as a total amount, I think we would be on an excellent start.

Mr. BOUCHER. What percentage of that should derive from the private sector?

Mr. WOODSON. Again, we believe that something in the 30 to 40 percent range from the private sector is something that should be accommodated by the private sector.

Mr. BOUCHER. So you are suggesting something on the order of $8 million Federal dollars?

Mr. WOODSON. I would have to redo my reverse math here. I believe your math is correct.

Mr. BOUCHER. Dr. Schora, would you like to comment on that?

Dr. SCHORA. I am not really expert in the phosphoric acid area, sir.

Mr. BOUCHER. Mr. Gutstein?

Mr. **Gutstein**. I would defer. There is a lot to be said about supporting the final step in an R&D program. We will come back to you with a written answer to that question.

I would like to make one comment. We in the Association, even some of the members who are directly involved in the more advanced technologies, firmly believe that all the fuel cell technologies will find a niche in the market one place or another. It is not a question of their competing. They will compete, but they will also find their own niche. You also have to look at the prospects for membrane type cells. They have also shown some recent improvements. They also may find a role in transportation.

Mr. **Boucher**. I gather that phosphoric acid is now about ready for demonstration and the other two lag somewhat behind. Has there been any expression of commercial interest from potential users for any of these three technologies, particularly phosphoric acid?

Mr. **Woodson**. If I might, as a proponent of phosphoric acid, inject myself and possibly you will tolerate a slightly longer answer. There has been extensive efforts made by Westinghouse and our competitors, to pursue the traditional marketplace. I note just recently that even our competitors have come to the same seemingly end-point that we have. I do not believe that that is an issue related to technology. I believe that is an issue related to the change, nature of competitiveness within the American electric utility and electric generation industries. We are continuing to work to find ways to bridge that gap.

There are great winds of change flowing through the generation side, the utility side of our business, which is bringing perturbation to all technology development programs at this point in time; winds of change that do not exist in foreign countries and the companies that are supported by those other governments.

Mr. **Gutstein**. May I make a reply also, Mr. Chairman?

Mr. **Boucher**. Yes, Mr. Gutstein.

Mr. **Gutstein**. The Association recently offered to a broker, the test of fuel cells at industrial sites. We have received expressions of interest from nine companies to participate in some sort of a planning or possibly to go forward with a demonstration of a fuel cell on-site industrial, possibly a chemical plan.

We have also received an offer of a 25-kilowatt unit from the Department of Energy at a nominal cost. We haven't gone far enough along to tell you exactly what our plans are, but at least within our own community there is interest in an on-site test, and it will probably be a phosphoric cell although I can't say for sure. We do have that kind of an interest.

Mr. **Boucher**. Thank you. It sounds like progress is, in fact, being made. That is certainly rewarding for our Subcommittee to hear, given the long association that we have had in supporting that research.

Gentlemen, I thank you very much for your testimony here today. Additional Members of the panel may have questions for you which they will propound in writing, and the record will remain open both for those questions and for your response. Thank you very much.

[Questions and answers for the record for panel 1 follow:]

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FUEL CELL ASSOCIATION'S RESPONSE

-to-

SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT

Hearing on the Department of Energy (DOE) FY1989 Authorization Request for Fossil Energy

Republican Member Questions for the Record for the Hearing of March 3, 1988 for Martin Gutstein, Executive Director, Fuel Cell Association (FCA)

QUESTION NUMBER 1: What is level of funding of the "Moonlight" Project in Japan for molten carbonate fuel cells?

a. How much of this funding is being provided by the government of Japan?

b. How much of this funding is being provided by private enterprise in Japan?

ANSWER TO QUESTION NUMBER 1:

Question 1a.

FCA does not have definitive information about this program. Nevertheless, we understand that the Japanese government is providing approximately $300 million (based on current exchange rates) for the molten carbonate part of the "Moonlight" project which runs until 1994.

Question 1b.

Again, FCA believes that substantial additional sums are being contributed by the private sector in Japan in support of the "Moonlight" project; however, we do not have any definitive information concerning the amount of cost-sharing. One estimate we have heard is that the private sector is putting up an amount equal to that of the Japanese Government's investments.

QUESTION NUMBER 2: How much funding is private industry in the U.S. providing for fuel cells?

ANSWER TO QUESTION NUMBER 2:

Again, FCA has no quantitative information about the past or current fuel cell R&D expenditures made by the private sector in this country, especially, those made by individual companies; FCA has no means of gaining access to this information, which is, typically, proprietary. We do, however, reflect the judgments of knowledgeable individuals in the field of fuel cells. Thus, over the past fifteen years, Federal support for fuel cells has amounted to approximately $350 million. Over this same time period, the combined spending for fuel cell R&D by natural gas and electric utility companies, the Gas Research Institute, the Electric Power Research Institute, and private companies involved in the development of this technology has been an amount of money approximately equal to or more than the Federal expenditure.

The magnitude of these investments in fuel cells by the private sector attests to their belief in the long-term commercial potential of the technology. In our opinion, the private sector will undoubtedly expand its support for fuel cell research, development, and demonstration in the coming years providing, however, a reasonable level of Federal support for the R&D continues. For example, we note that, fairly recently, several private companies not previously involved with the Department of Energy's programs have embarked on their own, privately-funded fuel cell R&D. At least one of the applications these companies are exploring, if commercially successful, would have a major impact on the economy and environmental well-being of the U.S. The current interest of these companies in fuel cells was made possible by a significant Federal program.

QUESTION NUMBER 3: Attached is a detailed list of funding recommendations for fuel cells presented to the Subcommittee by Dr. Bernard Lee, President of the Institute of Gas Technology. For each of Dr. Lee's recommendations, please indicate whether or not the Fuel Cell Association (agrees with) the project and funding levels supported by Dr. Lee. (PLEASE NOTE: The words within the parentheses were added by the Association to complete the meaning of the question.)

ANSWER TO QUESTION NUMBER 3:

The Fuel Cell Association is in the process of preparing its own comprehensive set of recommendations concerning the Department of Energy's fuel cell R&D activities and budgets for FY1989; these will be submitted to the Subcommittee in the immediate future. In advance of that submission, however, we wish to indicate to the Subcommittee that our recommendations will encompass and support those made by Dr. Lee. In other words, FCA fully endorses the recommendations of Dr. Lee as presented in the attachment sent to us.

Republican Member Questions for the Record
for the Hearing of March 3, 1988 for
FRANK C. SCHORA, PRESIDENT, M-C POWER CORPORATION

1. Who is the "major U.S. engineering company" teamed with M-C Power and IGT "to scaleup the IGT internally manifolded molten carbonate fuel cell technology under a two year cost shared DOE contract."?

   Currently under negotiation.

2. Is the "two year cost shared DOE contract" you refer to in your testimony underway?

   Yes, the contract was signed by DOE on February 24, 1988.

3. What is industry's share of this project?

   Under the provisions of the contract, the IGT team will provide cost-sharing up to $1.4 million.

4. What is the relationship of M-C Power Corporation and IGT?

   M-C Power is a freestanding corporation. It is not a subsidiary of IGT.

Additional Questions
Frank C. Schora
March 3rd hearing

1. If the Department supported the development of the IMHEX concept in FY1989 at $8.5 million, would you expect additional funding from the Department in the future? If so, how much?

   Assuming the Department of Energy fully funds the first year activities under the recently signed contract, the additional $8.5 million would be sufficient to fully fund the second year of the present contract.

2. In your statement, you mention that molten carbonate fuel cell development has taken 25 years to date, with another 5 to 7 years until commercialization. -- By comparison, how long has it taken to develop phosphoric acid fuel cells, which are also still not ready for commercialization?

   While the general molten carbonate fuel cell research effort has been going on for many years, major development has occurred only since the mid-70s. By comparison, phosphoric acid fuel cells began major development in the mid-60s.

SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT

Hearing on the Department of Energy (DOE) FY 1989 Authorization Request for Fossil Energy

Republican Member Questions for the Record for the Hearing of March 3, 1988, for NATHANIEL D. WOODSON

1. What is the schedule of the current Westinghouse-DOE joint program in phosphoric acid fuel cells?

The current Westinghouse-DOE joint program in phosphoric acid fuel cells is scheduled to complete the technology development and its reproducible verification by December 31, 1991. The program plan to achieve this schedule objective involves several key elements: These are: (1) screening and performance testing of improved technology areas in 1988, (2) selection and performance stability demonstration of an improved design baseline in 1989, and (3) demonstration of the improved technology scale-up in a 375 kW module in 1990 and 1991.

2. What level of funding is required in each of FY 1988 and FY 1989 to maintain the schedule of the current multi-year contract with DOE for phosphoric acid fuel cell development?

The funding required to maintain the schedule of the current multi-year contract with DOE for phosphoric acid fuel cell development is about $10.2M in FY 1988 and $13.4M in FY 1989. These funding values are exclusive of any DOE technical or administrative costs.

3. What technical problems remain to be addressed by the phosphoric acid fuel cell program before it can come to a logical conclusion?

The overall success of the Westinghouse-DOE joint gas-cooled phosphoric acid fuel cell technology development program is dependent upon development of solutions to a few remaining challenges. These are:

- Improved cell performance stability (12 to approximately 4 mV/1000 hr voltage loss)

- Improved cell module cost (to approximately $2600/kW with potential to $380/kW or less via automated production)

- Improved average cell beginning-of-life performance (690 mV to approximately 720 mV)

The CY 1988 and CY 1989 plans are structured to develop and subsequently demonstrate solutions to each of these impediments to commercialization challenges. Specific multiple potential solutions to the key elements adversely affecting cell performance and economics have been identified and are being pursued. For example, improvements in electrolyte transport and distribution, catalyst activity, matrix structure, and catalyst support corrosion resistance will reduce the rate of cell performance degradation. The stack production costs can be reduced by development of an integral edge seal, improved catalyst structure and activity, and improved manufacturing processes for the electrodes and plates. The average cell performance can be increased by reducing the cell resistance, improved electrode manufacture, and better catalyst activity.

4. What is the schedule of the current Westinghouse-DOE joint program in solid oxide fuel cells?

The contract for the current phase of the Solid Oxide Fuel Cell program at Westinghouse extends into 1989. The technical effort is to be complete by April 30 and the final report is to be submitted by August 31. Excellent progress is being realized toward the objectives of this current phase of the program; however, it is realized that the current contract scope does not cover the total requirements of commercialization.

5. What level of funding is required in each of FY 1988 and FY 1989 to maintain the schedule of the current multi-year contract with DOE for solid oxide fuel cell development?

The Government participation in the Solid Oxide Fuel Cell program is $7M in FY 1988 and an estimated $10M is needed in 1989 to maintain the Utility interest and the U.S. technological leadership. These represent the program as discussed with DOE and are only partially under formal contract at this time.

6. What technical problems remain to be addressed by the solid oxide fuel cell program before it can come to a logical conclusion?

The technical problem areas remaining to be addressed before the utilities can be expected to purchase commercial Solid

Oxide Fuel Cell plants include: Lifetime development (from the current few thousands of hours to at least 40,000 hour life) for both cell and system, including investigation of advanced processes, cells, module features and configurations, control systems, and interfaces with anticipated fuels such as gasified coal.

- Fabrication development, including mechanization, automation and other labor saving approaches to cost reduction to reach the module objective of approximately 350 dollars/ kilowatt.
- Up-scale of both cell and module, from the current 3-5 kWe through 20-25 kWe, 100-200 kWe and 1 MWe steps to the module for large electric power plants.
- Experimental units, operated by electric and gas utilities in actual user environments (both cogeneration and all-electric applications), at each of the above noted module ratings, for the purpose of establishing system technology (such as interface and operation with the electric grid) as well as market and especially regulatory confidence in this new and most promising technology.
- Engineering definition of proof-of-concept units in the hundreds of kilowatts range in a specific gas user application and in the 30 to 50 MWe range in a specific electric application for the confirmation of the total system.

Resolution of the above technical questions is seen as a six-year program requiring participation by Government, utilities, and suppliers. These steps are absolutely necessary if the U.S. is to realize a return on the investment made in fuel cells. A high level of non-Government participation has already been established in the Westinghouse Solid Oxide Fuel Cell program as evidenced by the record in 1987 when non-Government sources provided 71 percent of the support (10 million out of a total $14 million dollar expenditure.)

ADDITIONAL QUESTIONS
NATHANIEL D. WOODSON

March 3rd Hearing
Fossil Energy Research and Development
Subcommittee on Energy Research and Development

1. You state your concern that the lack of market definition for fuel cells makes it difficult to obtain private sector funding.

   -- Do you expect an improvement in the market opportunities for phosphoric acid fuel cells?

   -- If not, what do you see as the potential for phosphoric acid?

The electrical power generation market in the U.S. is currently undergoing one of the most dramatic changes in its history. The introduction of PURPA has created a new environment where small co-generation plants owned by independent operators are having a significant impact on new generation planning. Additionally, municipalities are becoming more interested in being self generators rather than simply buying electricity from the grid.

This change in the market should increase the long-term attractiveness of PAFC's, since municipalities and the independent co-generation market will require smaller plants locatable in close proximity to the load. For this type of market, the low emissions, high part-load efficiency, and small size of PAFC's offer many advantages.

We therefore do not interpret the reduced interest of the traditional power producers as a reduction in the future market opportunities. Furthermore, the emergence of a high degree of interest in Europe is very encouraging and represents the potential for a significant export business. Unfortunately, with the market currently undergoing this period of transition, it is difficult to obtain hard data on which to make reasonable investment decisions. The Japanese and Europeans have taken action to help solve this dilemma by moving ahead with demonstration plants. We must also keep a viable program intact during this transition period and it should involve demonstration facilities. Without such facilities, market projections will remain uncertain and we face the very real possibility of losing our technological lead.

2. It appears that you have been more successful in obtaining development partners for your solid oxide tubular commercialization effort than for your phosphoric acid work.

    -- Why do you think this is the case?

Both the solid oxide and phosphoric acid programs have been well supported by the industrial community. The apparent differences in support you observe are the result of the structure of these programs and the current stage of their development. The solid oxide program is at an earlier stage of development and is currently addressing small-sized units. This allows program support to be from many sources with relatively small increments of funding. The phosphoric acid program received similar support in terms of dollars during the same stage of its development. This support moved the program forward to where it is now ready for a multi-megawatt demonstration.

This demonstration plant represents the single largest investment to date and, as discussed in our response to your first question, it must be made during a time of transition in the marketplace. We firmly believe that the future of fuel cells should include the multi-megawatt market and a way must be found to demonstrate this promising technology.

PANEL 2: COAL R&D

Mr. **BOUCHER**. Our second panel today will discuss coal research and development, and consist of Mr. Vincent Coates, representing MHD Industrial Forum; Dr. Dan Hartley of Sandia National Laboratory; Dr. Lawrence Wisdom, representing Hydrocarbon Research, Inc.; and Dr. Thomas G. Squires of the American Chemical Society.

We will be happy to hear from these gentlemen. I would encourage you once again to please summarize your statements and keep your statements to five minutes. We will make a part of the record, the full text of your statement.

First, we will hear from Mr. Vincent Coates.

STATEMENT OF VINCENT J. COATES, JR., VICE PRESIDENT, MHD INDUSTRIAL FORUM, WASHINGTON, DC

Mr. **COATES**. Thank you, Mr. Chairman. Mr. Chairman, with your permission, I would like to request permission to add two statements for the record; one by Dr. Susan Wu, who is in charge of the University of Tennessee's MHD program; and also, from Dr. Arora, who is Chairman of the EEI, MHD task force, in which he endorses MHD.

Mr. **BOUCHER**. Without objection, those statements will be made a part of the record.

[See Appendix 1.]

Mr. **COATES**. Thank you, sir. First, I would like to begin my five minutes by expressing my appreciation to this Committee for the long support which it has given to MHD. Clearly, without your continued interest and support, it is quite clear the program would have gone nowhere.

Magnetohydrodynamics is a rather complicated word which may explain why so frequently people don't understand its benefits. In fact, just last week the Department of Energy's representatives before the Interior Appropriations Subcommittee here in the House side, testified that MHD had no benefits.

I would like to take one or two minutes to describe to you exactly what MHD is and why it is not terribly complicated. In the last Century, a man named Faraday figured out that if you moved a conductor of electricity, such as copper wire, through a magnetic field you could make electric power. A few years later someone else came along and made a copper wheel which they rotated through a copper field.

In order to rotate the magnetic field, they first used a reciprocating engine, and later used turbine engines. In order to make the turbine engine operate, they used coal or any fossil energy, and in more recent years a nuclear energy.

What MHD does is to eliminate the rotating machinery and all the rest of the equipment, and use the hot gas that comes from the combustion of coal. The hot gas is a conductor of electricity and so as it moves through the magnetic field, you have electric power.

It has a number of advantages which have been repeated over the years. I am not going to go into all of them, but there are one or two. One, for example is, the environmental benefits. In the first place, it will have a very positive impact upon the reduction of the greenhouse effect.

Secondly, it will reduce NO_x and SO_x about 99 percent of the SO_x. It is all inherent in the machine. You don't have to add anything onto the generator in order to remove SO_x and NO_x. Another advantage is that an MHD generator produces power by taking the power out of the gas stream. As it exits in the MHD generator, there is a lot of hot gas that is left over which is used to operate a conventional power plant.

Those two points; one, by elimination of much of the rotating equipment and by combining it with a conventional power plant you can increase the efficiency to a point where a well-developed MHD generator would operate at about 60 percent. It offers the advantages of being able to upgrade existing power plants by MHD unit to it. You don't have to buy new land and you don't have to build a new plant. That is how MHD works and those are the advantages.

Now you might ask, well, you are representing the MHD Industrial Forum, we would expect you to say that. I would like to call to your attention, DOE's second report to the Congress on emerging clean coal technologies, which goes into more detail on all of these points. In the document which I just submitted, Dr. Arora endorses the MHD program.

Where do we stand currently? At the present moment in carrying out the so-called redirected plan or MHD development which DOE formulated in close consultation with industries several years ago and then formally submitted to the Congress, this year the Department let four major contracts to perform the proof-of-concept program which will enable the industry to proceed with a retrofit plant in about five years. But, that's up to you.

Whether or not the program goes to the retrofit at a point where industry will contribute 50 percent, is entirely up to you. In order to make the program go this year, we need $41 million. The other number—for a total over the next five years—$187.9 million by 1992.

If you stretch out the program, we won't get there and we will end up buying MHD components from the Soviet Union which has a very aggressive program.

I thank you for your time, Mr. Chairman.

[The prepared statement of Mr. Coates follows:]

SUMMARY

Statement
of
Vincent J. Coates, Jr., Vice President
MHD Industrial Forum
Suite 1100, 900 17th Street, N.W.
Washington, D.C. 20006

to

The Subcommittee on Research and Development
Committee on Science, Space and Technology
United States House of Representatives
Washington, D.C.

March 3, 1988

MHD power generation is a method of producing electric power by using a high temperature gas to replace the rotating equipment used in conventional plants.

DOE´s Second Report to the Congress on Emerging Clean Coal Technologies in May 1987, stated the technical, economic and environmental benefits of MHD power generation as well as the cost and other advantages that would derive through retrofitting existing power plants with MHD retrofit units. The report concluded that "the construction of MHD retrofit power plants appears to be a natural progression in MHD development after the satisfactory completion of the Proof of Concept program."

During 1987 DOE awarded four major multi-year contracts to implement this Proof of Concept Phase (POC) of MHD development. The POC implemented the DOE "Redirected MHD Program" plan formulated by DOE in consultation with industry and submitted to Congress in 1984.

The contracts call for the design and fabrication of components to allow for integrated testing of a complete MHD flow train at the Government owned Component Development Integration Facility (CDIF) in Montana.

A second contract was awarded to Babcock and Wilcox, Ohio, to make modifications to the Government Coal Fired Flow Facility (CFFF), operated by the University of Tennessee´s Space Institute, necessary for testing equipment associated with the Bottoming or Steam Cycle portion of a combined MHD generator.

A third contract, also awarded to Babcock and Wilcox, calls for developing the Seed Recovery/Regeneration System.

The last procurement involves contracts to Westinghouse Corporation, Pennsylvania, and the MHD Development Corporation, Montana, to prepare conceptual designs for a retrofit MHD plant. (Retrofitting an MHD unit to an existing utility plant.)

The industry's view of the budget required to complete the Proof of Concept program which is believed to closely parallel DOE's budget planning are as follows:

1988	1989	1990	1991	1992	Total
35	40.9	43	40	29	187.9

Assuming no unforeseen technical problems, DOE's schedule can be met if adequately funded. If the funding falls below the budget plan, the schedule will have to be stretched. The result will be that the program will cost more and the U.S. will fall further behind the Soviet Union, which continues to make excellent progress. Under Gorbachev's leadership, the USSR is making a determined effort to increase its international trade even to the point of aggressively marketing its space launch and satellite services. Be assured that MHD is on its list of technologies to be made available. Many nations currently involved in MHD development do not have the resources to compete with the USSR's program but realizing the many benefits of the technology they will be a ready market.

We urge the Subcommittee to authorize at least $40.9 million for MHD development in FY 1989 and to direct DOE in the strongest terms to complete the POC Program on the schedule it provided for in its plan, so that the Retrofit phase, which industry will cost-share 50%, will start on schedule.

Statement
of
Vincent J. Coates, Jr., Vice President
MHD Industrial Forum
Suite 1100, 900 17th Street, N.W.
Washington, D.C. 20006

to

The Subcommittee on Research and Development
Committee on Science, Space and Technology
United States House of Representatives
Washington, D.C.

March 3, 1988

I am pleased to be here today to report to you from an industry viewpoint on the status of the Department of Energy's MHD (Magnetohydrodynamic) Electric Power Generation development program.

Like all other conventional base load power plants, MHD converts heat energy to electric energy using the same law formulated by Faraday in the last century. The difference is that the MHD system extracts electrical power directly from the hot gases without the intermediary boiler, turbine and rotating equipment. In fact, it represents the most significant advance in the Faraday process since the introduction of turbines in the late 19th and early 20th century.

It is this simplicity which contributes most to the efficiency increase that MHD enjoys over conventional fossil plants. Even more when compared to nuclear plants.

The net result is that a coal burning MHD power plant will have significantly higher efficiency (50% better than a conventional fossil plant), lower environmental intrusion, and lower generating costs than conventional electric generating plants. DOE acknowledges these advantages in its May 1987 Second Report to Congress on Emerging Clean Coal Technologies.

Furthermore, experiments at the University of Tennessee Space Institute have demonstrated that SOx, NOx and particulate emission levels from a coal-fired MHD power plant can easily meet the existing New Source Performance Standards (NSPS). In fact, NOx emissions will be one seventh of those permitted by the standard, SOx will be one third, and particulate about two thirds of the NSPS allowable limits, see attachment 1. MHD power plants can use any type of coal -- eastern or western -- and will be less costly to build and operate.

It is no wonder that many nations around the world have MHD development programs. The USSR is currently building a commercial size 500 MW power plant which puts them well ahead of all other countries, including the U.S. who demonstrated the world's first successful MHD generator.

I am pleased to report to you that the U.S. program is now back on track and if we sustain the momentum, we can overtake the USSR. We do, by the way, surpass the Soviets in the sophistication of our technology, but when it comes to the market place, a working device wins every time, as Henry Ford demonstrated with his Model A.

This year (FY 1988), the department awarded four major procurements called for in DOE's "Redirected MHD Program", also referred to as the Proof of Concept Phase (POC). The plan, formally submitted to Congress in 1984, focuses on the engineering, development and integrated long duration testing of the principle MHD components and preparing a conceptual design of an MHD Retrofit Power Plant. Completion of these four procurements will permit the culmination of a successful POC test program. This information will provide the data base for the next phase of development, which involves retrofitting an MHD unit to an existing electric utility plant and operating it under commercial conditions.

The "Redirected MHD Program" was formulated by DOE in close consultation with Industry after public hearings in which senior DOE fossil energy officials conducted extensive reviews of MHD's technical, economic and environmental benefits. Participants in those hearings represented MHD Research and Development organizations, DOE's national MHD test facilities, universities, the National Magnet Laboratory, utility companies, utility equipment manufacturers, power plant design and engineering firms and other interested organizations.

A completed coal-fired MHD power plant will be comprised of two major subsystems. The first subsystem is the MHD topping cycle and the second is the steam bottoming cycle. Both the topping cycle and the bottoming cycle produce electrical power that, when combined, represents the total output power from the plant. The combustion gas temperature required by the MHD process is typically in the range of 4500 F to 5000 F, which is much higher than required for a conventional steam power plant (typically 3200 F to 3500 F). The gases exiting the MHD topping cycle retain a great deal of heat at a relatively high temperature (typically 3600 F). Thus, the energy in these gases can be recovered in the bottoming cycle and used to generate steam for producing electric power to augment that from the MHD topping cycle.

A description of the four major procurements awarded by DOE in FY 1988 to carry out the Proof of Concept effort as provided for in the "Redirected MHD Program" follows. Much of the following is excerpted from "An Overview of DOE and SDIO MHD Program Activities", AIAA 26th Aerospace Science Meeting, January 11 - 14, 1988.

Integrated Topping Cycle: In September 1987, a fifty-one month Integrated Topping Cycle contract was awarded to a team led by TRW, Inc., California. Prototypic hardware to be provided under this contract will include a 50-MW(t) coal-fired combustor, a 50-MW(t) MHD channel, a diffuser, an advanced power conditioning/inverter system, and appropriate spare parts. Systems engineering activities will include power train/facility integration, test planning/review, and power train performance analyses.

In addition to providing for overall integration of the work, TRW will focus on all aspects of the POC effort associated with the coal-fired combustor. The development effort associated with the MHD channel and diffuser and the power conditioning hardware will be conducted by the Avco Research Laboratory, Textron, Inc., Massachusetts, and the Westinghouse Electric Corporation, Pennsylvania, (respectively), as subcontractors to TRW, and will be supported by STD, Inc. of California.

The POC test program that was proposed provides for operation of prototype hardware for a total of about 1000 hours at the Government-owned Component Development and Integration Facility (CDIF), using eastern and western coal.

To permit private industry to assume an active role in the MHD POC program, an MHD Technology Transfer, Integration, and Review Committee was organized as part of this contract. The committee consists of a broad cross section of personnel representing contractors participating in the major MHD program activities, equipment suppliers to the electric utility industry, potential users of MHD technology, and other parties cost-sharing the program.

Integrated Bottoming Cycle: The second major procurement was awarded to Babcock and Wilcox, Ohio, to modify the coal handling and pulverization system at the Government owned Coal Fired Flow Facility (CFFF). This will permit the processing of both eastern and western coals. In addition, Babcock and Wilcox will design, fabricate and install an automated system for collecting spent seed and ash materials and complete the design of an intermediate temperature air heater.

These modifications will allow durability testing of the complete bottoming cycle for a period of about 4000 hours (2000 hours for eastern coal and 2000 hours for western coal).

Seed Recovery/Regeneration: For economic and environmental reasons, it is necessary that the potassium seed, used to increase the performance of the MHD generator, be recovered from the MHD cycle and regenerated so it can be recirculated back into the cycle.

To develop the seed recovery/regeneration system, DOE awarded three contracts in a competitive two phase procurement. Phase I, which is expected to be completed in about one year, includes bench-scale research and assessment of the technical and economic value of each specific regeneration process. Upon completion of Phase I and evaluation of results, DOE may select one process contractor to design, construct and operate a system large enough to confirm process viability.

The awards were made to Babcock and Wilcox, Ohio; the University of Tennessee Space Institute (UTSI), Tennessee; and TRW, Inc., California. Babcock and Wilcox will study an aqueous carbonate process, UTSI will test a process based on formate chemistry, and TRW will develop its "Econoseed Process."

Retrofit Conceptual Design: It has long been recognized that retrofitting MHD power systems to existing plants enables utility companies to increase capacity without building a completely new plant which would mean acquiring a new site with attendant lengthy siting and other regulatory requirements. Accordingly, after consultation with the private sector, DOE agreed to undertake the conceptual design of a retrofit plant as an element of the POC program.

At the end of FY 1987, conceptual design contracts were awarded to the Westinghouse Electric Corporation, Pennsylvania, and the MHD Development Corporation (MDC), Montana, for study of the site-specific retrofitting of an MHD system to an existing fossil-fired utility plant. The Westinghouse study will be based on Gulf Power´s Scholz Plant located in Sneads, Florida, while the MDC study will be based on Montana Power Company´s Corette Plant in Billings, Montana.

Utility participation on each of these contracts is essential to the success of the overall effort. As outlined in the solicitation for the conceptual design, DOE sought to identify at least one host plant for the purpose of conducting the conceptual design and, ultimately, to have a utility or a utility and A&E team develop a conceptual design of the retrofit, together with schedules and cost estimates for the preliminary design, final design and construction of the retrofit. The DOE anticipates that upon completion of the conceptual design effort, a formal plan for financing the project will also be developed by the host utility.

DOE maintains two government-owned national MHD test facilities. A brief description of these activities in FY 1987 follows.

DOE´s Component Development Integration Facility, (CDIF), located in Butte, Montana is designed for testing MHD components and power trains representing the MHD portion of a commercial MHD power plant. It will be used to test the Integrated Topping Cycle which is a major component of DOE´s "Proof of Concept" activity.

CDIF accomplishments during 1987 include the completion of seed testing to optimize performance and installation and testing of a new nozzle section for the second stage of the combustor. In addition, CDIF assembled, installed and tested new channel forward peg sidewalls to improve electrical isolation between the anode and cathode walls, reduce electrochemical sidewall corrosion and enhance diagnostic capability for MHD testing; and they refurbished, installed, and tested the channel forward anode walls.

DOE´s Coal Fired Flow Facility (CFFF), located on the campus of the University of Tennessee´s Space Institute (UTSI) is charged with providing data on the performance and durability of components that closely simulate an MHD bottoming-cycle subsystem. These components provide for heat recovery, i.e., steam generation and air preheat, for the removal of spent seed/ash and slag, and for the cleaning and treatment of the effluent process flow.

During 1987, researchers at UTSI successfully completed 205 hours in·the CFFF, the longest duration test in history of a coal-fired MHD bottoming cycle. The previous record for long duration testing of a coal-fired MHD system was 70 hours and was accomplished at the CFFF in 1986. The significance of the test is reflected in the fact that in the early 1980´s, test periods of five to ten minutes were considered long in a coal-fired MHD system.

Extensive data was obtained on bottoming cycle component performance, materials erosion and corrosion, ash deposition, NOx and SOx emission levels, particulate control, and heat transfer. The data obtained represent the first step in evaluating the long term effect of potassium seed on materials performance and on the operational characteristics of the steam bottoming cycle components.

DOE anticipates completing the POC phase of this program in 1991. This schedule is presently on track according to information presented at the DOE sponsored MHD contractor meeting held in January of this year in Pittsburgh.

Other DOE Contractor Activity: STD Research Corporation, California, designs and builds MHD generators using extremely sophisticated computer modeling codes to produce the highest net power output and efficiency MHD generators. These design and fabrication techniques are used to enhance the performance of future power trains.

Mississippi State University plays an essential role in the program as the principle contractor specializing in the use of highly sophisticated diagnostic test equipment which it developed and used in support of flow train evaluation.

While DOE does not reveal its budget planning to the public, enough is known about the internal working of DOE to be credibly certain that the department's MHD budget was very close to the industry estimate. The total projected cost to complete the Proof of Concept Program is :

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We urge the Subcommittee to authorize at least $40.9 million for MHD development in FY 1989 and to direct DOE in the strongest terms to complete the POC Program on the schedule it provided for in its plan so that the Retrofit Phase, which industry will cost-share 50%, will begin on schedule.

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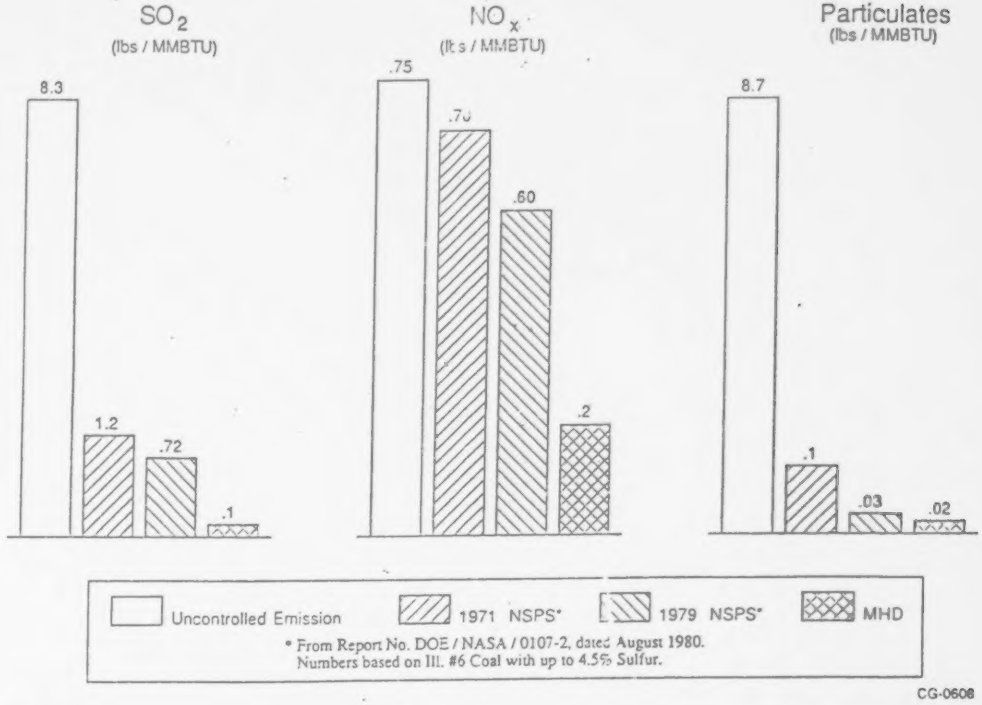
Figure 1.

Emission Levels from Coal - Fired MHD Power Plant



* From Report No. DOE / NASA / 0107-2, dated August 1980. Numbers based on Ill. #6 Coal with up to 4.5% Sulfur.

The University of Tennessee Space Institute
Tullahoma, Tennessee

Mr. Boucher. Thank you, Mr. Coates. Dr. Hartley, we will be happy to hear from you.

STATEMENT OF DR. DANNY L. HARTLEY, VICE PRESIDENT, ENERGY PROGRAMS, SANDIA NATIONAL LABORATORIES, ALBUQUERQUE, NM

Dr. Hartley. Thank you, Mr. Chairman, for inviting me to speak to you about my views on fossil energy research needs. I am Dan Hartley, Vice President of Sandia Laboratories. I am responsible for all of our energy programs, approximately 1,000 FTE's out of Sandia's total of 8,250 scientists, engineers and support people.

We have program responsibilities in virtually all aspects of DOE energy programs from BES to nuclear, fossil, solar, conservation, and waste management. I have been directly involved in these activities for 15 years, and I am proud of our record of accomplishments and of our achievements in technology transfer, especially in the fossil energy areas.

All of us in management at the National Laboratories have periodically set up study groups to advise us on critical energy needs. A consistent message comes from all of our groups independently: this country will rely on coal, and on the industry that converts and utilizes coal in an ever-increasing amount and with ever-increasing environmental concern.

We are also consistently concerned about the lack of coal-related science and engineering in our universities and at National Laboratories. It is our responsibility to be concerned about this, and it is our mission to apply our resources to aid in the solution of the country's most critical energy problems.

Fundamental coal research is certainly one of the most critical energy science needs that we have. Yet today, only three DOE National Laboratories have any significant role in coal research: Oak Ridge in materials research; Argonne in instrumentation; and Sandia in conversion and in combustion. Even these activities are limited.

In response to this situation, we spent the last three years working with top management from other National Laboratories—Los Alamos, Lawrence Livermore, Lawrence Berkeley, Idaho National Engineering Laboratory, Sandia Labs in Livermore and in Albuquerque—to develop a concept that will appropriately utilize the resources of the DOE National Laboratory system in partnership with universities to address critical coal research needs.

We have reached an understanding of our individual strength and styles, and have arrived at a consensus of the nature of the such a program. We have done this in consultation with industry, university and DOE personnel.

As a means to focus such an effort, a Coal Science Initiative is strongly recommended. The objective would be to develop an increased, integrated, self-consistent understanding of the structure, composition and reactivity of coals, and using that information to allow design of improved conversion and combustion techniques.

The very latest equipment and techniques of the National Laboratories and universities will be brought together in a coordinated team fashion. This multi-disciplinary National Lab university team approach would take advantage of an unsurpassed collection of research staff, instrumentation, computers and experience, and it will require continuity of funding. To support programs involving the several participants, funding requirements for fiscal year 1989 are estimated at $25 million with a plan of execution through the year 2000.

While this panel is addressing coal, I also strongly recommend increased DOE program support in geosciences in support of oil, gas and oil shale. Past ERAB reports and other endorsements have produced compelling logic for the role of geosciences in aiding the production of our difficult-to-recover domestic resources.

Again, in geosciences, the National Labs have contributed major technologies; drilling technology and downhole instrumentation and reservoir characterization. These kinds of activities need to be more vigorously supported by Federal funding since they have such high leverage on national economics.

At Sandia, we benefit from the co-location of several geoscience programs at our Lab: the Continental Scientific Drilling Office of BES; geoscience and instrumentation for tight gas at the multi-well experiment for Fossil Energy; EOR activity for Fossil Energy; reservoir characterization for the Strategic Petroleum Reserve; geotechnology for WIPP—the Waste Isolation Pilot Plant—and for the Nevada commercial repository; and geotechnology in support of verification for nuclear testing.

In order to link our geosciences and geoengineering as it applies to all offices of DOE, we are establishing a Geosciences Research Park at Sandia Laboratory in Albuquerque. It will be operated as a national user facility, similar to our Combustion Research Facility at Sandia Livermore. The initial phase of the park is a geosciences research laboratory and simulation facility which we have requested through BES, but Fossil Energy would benefit from such a multi-program facility.

In summary, we at Sandia feel that increased R&D support for coal science and for geosciences is critical to the country's economic and national security. The National Laboratories have made important contributions in the past and we stand ready to do our part in the future.

We believe our specific proposals for our Coal Science Initiative and a Geosciences Research Park can provide the focus and leadership that are needed in energy research. Thank you, Mr. Chairman.

[The prepared statement of Dr. Hartley follows:]

THE NEED FOR AN EXPANDED FOSSIL ENERGY PROGRAM

Submitted to:

The Subcommittee on Energy Research and Development
of the
House Science, Space and Technology Committee
The Honorable Marilyn Lloyd, Chairwoman

Submitted by:

Danny L. Hartley, Vice President
Energy Programs
SANDIA NATIONAL LABORATORIES
Albuquerque, New Mexico

March 3, 1988

THE NEED FOR AN EXPANDED FOSSIL ENERGY PROGRAM

INTRODUCTION

Thank you for inviting me to present the views of Sandia National Laboratories regarding the federally-supported fossil energy R&D program. Our views, I believe, will be consistent with those voiced by a number of other qualified sources. We recognize the pressing budget issues that face the nation and we are aware of the current plentiful supply of affordable energy. Yet we are firmly convinced that future disruptions and limitations in this supply are a real possibility and we believe the potential impacts on our nation are serious. Thus, we conclude that a vigorous and stable federal R&D program, with ample funding to develop technologies that will increase our domestic energy supply base, is prudent and I hope to convince you that the national labs can and should play an essential part in that.

ROLE OF THE FEDERAL GOVERNMENT

All of us are aware of the direct relationship between an adequate, affordable energy supply and our individual and national well-being. Supply disruptions cause economic chaos and in the end can threaten our national security. Since the federal government has a clear responsibility to ensure our overall security, it must therefore consider the need for and take action to ensure an adequate energy supply. One can suggest several broad options that the federal government could invoke in the discharge of this responsibility, but I wish to address only a technology development option.

There is in place today a collection of private industries that directly provides for our energy demands and they generally have an outstanding record of meeting our collective needs. However, under certain circumstances, their need to satisfy short- and intermediate-term economic constraints can seriously limit their ability to devote significant amounts of their resources to solving longer range problems. For example, it is well known that oil prices have been controlled for the last several years by an international cartel. This control not only limits the dollars that a U.S. company can prudently invest in developing advanced oil and gas recovery techniques, but it also limits R&D investments in unconventional processes such as recovery of oil from shale and conversion of coal to liquid and gas fuels. Yet, there can be little question that in time these resources, which far surpass our dwindling, conventional oil and gas reserves, will become an increasing part of our total energy supply mix. Given this reality, the government's role is to support an R&D program that emphasizes the development of advanced technologies that will increase our domestic energy supply. This program should involve industry, universities, and national laboratories along with the energy technology centers; it should provide for a long-term stable commitment; and it must ensure technical interchange and technology transfer to industry for appropriate implementation. With this background, I would like to specifically address two topics that I believe warrant particular attention and additional support.

COAL RESEARCH

The U.S. possesses abundant coal reserves, estimated by some to represent a 4- or 5-hundred year supply. Although coal currently provides less than 25% of our energy demands, it accounts for about 75% of our combined coal, petroleum, and gas reserves. Therefore, to take full advantage of this resource in the future, not only must we develop technologies to burn coal more efficiently and with less environmental impact, but we must also develop improved and economically competitive means to convert this hydrogen-deficient, heterogeneous solid to high value liquid and gas fuels. In this way, coal can provide a means to directly offset declining oil and gas supplies, we can develop technology to advance our competitive position worldwide, and coal can be a key to the future of a secure U.S. domestic energy supply.

Expanded use of coal is not limited by the need for improved exploration and/or recovery. Rather, the critical need is for better conversion and utilization. This need can be addressed by an expanded, exploratory R&D program whose goal is to meet the need stated above; that is, we must look beyond present-day uses of coal and develop technologies that not only will allow cleaner, more efficient combustion but also will permit conversion to liquids and gases. In that sense, a long-term, science-based R&D effort would be directed at technology and processes to be implemented beyond the Innovative Clean Coal Technology (ICCT) program whose goal is to "conduct cost-shared . . . projects to demonstrate emerging clean coal technologies that are capable of retrofitting or repowering existing facilities."

There are R&D elements within the current fossil energy program that we believe provide an excellent beginning for developing needed advanced conversion technologies. For example, at Sandia National Laboratories in Albuquerque, progress has been made in reducing pressure requirements for liquefaction; much has been learned about catalyst deactivation; innovative new catalysts have been developed; and improved combined stage liquefaction processes have been identified. At our Combustion Research Facility in Livermore, California, we are using the latest in diagnostic and modeling techniques to understand the physics and chemistry of coal combustion and to define fundamental relationships between coal rank and quality and the combustion environment. All of this is important to enlarging our use of coal and the work should be expanded so that even more progress can be made. In a like manner others have contributed important new understanding to this and other fossil technologies.

Two current ideas -- preconversion chemistry and computer aided molecular design -- illustrate the need for increased support. Preconversion processes can be a key to increasing yield and reducing conversion costs. We must find ways to set the stage for the effective final conversion by doing "right" things in the initial conversion step(s). We must learn how to favorably control the initial treatment chemistry, to provide better cleaning and solids reduction, and to prevent unfavorable chemical reactions. Similarly, using computer aided molecular design, we are beginning to understand how to selectively design catalysts for favoring specific processes. This capability could have significant impact on a variety of topics ranging from better control of the yield distribution in indirect liquefaction processes (Fischer-Tropsch conversion) to the conversion of methane to liquids.

A major mission of the DOE national labs is to apply it's resources to aid in the solution of our country's most critical energy problems. Fundamental coal research is certainly among the most critical energy science needs we have, yet today only three DOE national laboratories have any significant funding in coal research: Oak Ridge in materials research; Argonne in instrumentation; and Sandia in conversion and, at our Livermore site, combustion. Even these activities are relatively limited. In response to this situation, we have spent the last three years working with top management from other national labs -- Los Alamos National Lab, Lawrence Livermore National Lab, Lawrence Berkeley Laboratory, and Idaho National Engineering Laboratory -- to develop a concept that will fully utilize the resources of the DOE national laboratory system, in partnership with universities, to address critical coal research issues. We have reached a mutual understanding of our individual strength and styles and have arrived at a consensus on the nature of such a program and on the roles of the national laboratories. We have developed our ideas in consultation with representatives from university and industrial research groups, as well as with DOE personnel. There is a consistent voice for such an expanded effort.

As a means to focus such an effort, a COAL SCIENCE INITIATIVE is being recommended. The objective of such an initiative would be to develop an integrated, complete, self-consistent picture of coal, based on its structure, composition and reactivity, that can then be used to guide development of improved conversion and combustion techniques. A key to meeting this objective is that the very latest techniques and equipment in our national laboratories and universities will be brought to bear on this problem in a coordinated fashion. This concept will afford occasions for graduate and post graduate students to utilize equipment and to perform research at our national laboratories and for the exchange of professors and laboratory staff. Results and progress will be regularly shared with and reviewed by other members of the effort to create a "cooperative competitiveness" and to ensure maximum progress toward this integrated picture. DOE personnel will be a continuing part of these discussions to ensure that the work is complementary to and not duplicative of other coal R&D tasks. This multi-disciplinary national laboratory/university team approach would take advantage of an unsurpassed collection of research abilities, expertise, diagnostic techniques and instrumentation, computers and coal related experiences to develop a highly focussed, goal-oriented program. It is important to recognize that reasonable assurance of multi-year funding is necessary in order to create the stable associations necessary to assure progress on this complex and difficult topic.

In this initiative, cooperation among all laboratory and university participants and coordination with appropriate DOE coal program personnel will be essential. Sandia National Laboratories is prepared to serve as technical integrator for DOE in this program. To support programs involving several participants, funding requirements for FY89 are estimated at $25,000,000. The first year program will allow for technical refinement and completion of a ten-year plan of needed research activities and required funding. Some research activities will be strengthened and several laboratory-university programs will also be initiated in FY89.

GEOSCIENCE AND GEOTECHNOLOGY FOR OIL AND GAS

Since the pressure from escalating liquid fuel imports and international trade deficits is readily obvious and not likely to attenuate in any foreseeable future, we must expand our base of geoscience and geotechnology applied to oil and gas discovery, access, and extraction. Past ERAB reports, IOCC endorsements, and other testimonies have produced similar conclusions regarding the importance of geosciences to our energy future. The potential value of this research and development is enormous since approximately two-thirds of our domestic oil resources remain in the ground after primary and secondary recovery. Likewise, decades of natural gas resources lie in tight sandstones or in deep basins in wait for new technology which will allow predictable, economic recovery.

A combination of laboratory and field-based research and development will be necessary to accomplish these recovery objectives. A continued development of advanced instrumentation systems -- such as downhole acoustic sources and receivers as well as new electrical and electromagnetic diagnostic techniques -- will allow location of residual oil and determination of reservoir fracture geometries and heterogeneities. This in turn leads to an increased, fundamental understanding of reservoir characteristics and facilitates advancement in drilling, stimulation, and novel recovery technologies.

In cooperative alliances with industry, Sandia National Laboratories serves to break the ground for new technology innovation, development, and application. In many cases the applicable concept originates in one of the applied science projects (such as supported by DOE Basic Energy Sciences) and proceeds through an advanced development phase in an energy technology program such as Fossil Energy. Recent examples of the success and value of this approach are a device for measuring the anelastic recovery of strain in cores removed from drill holes and devices for transmitting and receiving acoustic signals downhole. Both developments have major significance to petroleum location and recovery and have been quickly accepted by industry. These kinds of activities need to be more vigorously supported by federal funding since they have such high leverage on our national economic structure.

In order to allow an efficient linkage between geoscience and geoengineering as it may apply to fossil, geothermal, and other energy pursuits, Sandia is recommending a Geoscience Research Park at Sandia National Laboratories in Albuquerque, New Mexico. This facility, operated as a National Users Facility for scientists and engineers from other federal laboratories, industrial organizations, universities, and state organizations, has been recommended to DOE as a BES funded facility but fossil energy R&D would directly benefit from such a multi-program facility. The initial phase of this facility would be a Geoscience Research Laboratory and Simulation Facility which would bring together the investigators from a wide range of disciplines in both science and engineering to derive solutions to the complex problems of energy resource discovery, access and extraction.

SUMMARY

An adequate, affordable energy supply is crucial to our national security and well being; yet our ability as a nation to ensure that supply is increasingly tenuous. We contain within our borders large quantities of energy in forms that are not presently economic to recover and utilize. Specifically, oil from advanced tertiary recovery techniques, gas from unconventional sources, coal liquids produced by better conversion techniques, and oil from shale and tar sands are not now a part of our domestic base. Further, the international control of oil prices currently makes it unlikely that our energy supply private sector can mount a stable R&D program -- particularly addressed at the more unconventional and, coincidentally, plenteous resources. Therefore, a role for the federal government is clearly established.

We at Sandia feel strongly that increased R&D support for Coal Science and for Geoscience is warranted. We further believe that the national laboratories are well matched to be a part of these R&D programs. Sandia has made key contributions in the past in fossil energy programs and we are positioned and ready to do our part in this even more challenging undertaking.

Mr. BOUCHER. Thank you, Dr. Hartley. Dr. Wisdom.

STATEMENT OF DR. LAWRENCE I. WISDOM, EXECUTIVE VICE PRESIDENT, HYDROCARBON RESEARCH, INC., LAWRENCEVILLE, NJ

Dr. WISDOM. Mr. Chairman and Members of the Subcommittee, Hydrocarbon Research appreciates the opportunity to testify today on the fossil energy research and development budget request. HRI, over its 45 years, has played a very key role in the development of our domestic resources into clean fuels.

However, it is unfortunate today that the United States is without an adequate long-term energy policy for the lack of a short-term energy crisis in the form of long lines at the gas pumps. Unfortunately, there is a crisis in our view. Domestic oil production fell 4.4 percent last year, while oil imports continue to rise above 40 percent of domestic consumption.

Energy policy constrains foreign policy today. The United States Naval forces in the Persian Gulf prove that. The choices available to the U.S. today will further be constrained as dependency on foreign oil climbs past 50 percent sometime in the next decade. We don't lack options today. What we lack is a sense of urgency in exercising them.

I come before you today as a representative of HRI, as a solid supporter of a balanced budget, and we understand that means budget restraints. The large Federal deficits of recent years rule out huge R&D expenditures today.

But clearly it is in the interest of the American people to put together a responsible balanced program that allows for fundamental fossil energy research, as well as a continued development of the Nation's most promising technologies. I regret to say that we at HRI do not believe the Fossil Energy R&D budget submitted by the Administration comes close to meeting that need.

As this Subcommittee knows, HRI over the years has been a leader in the field of direct coal liquefaction. During the late 1970's and early 1980's, the United States Department of Energy funded the construction of three coal liquefaction demonstration plants, including HRI's H-COAL process at Catlettsburg, Kentucky.

This plant demonstrated oil yields of slightly over three barrels of oil per ton of coal, which confirmed the work done at our research laboratory in both our bench and PDU. Unfortunately, this plant closed down in 1982. In 1983, DOE awarded a two-year, follow-on contract to pursue research in this field at our bench and PDU level. In 1985, this program was again continued as a two year follow on program.

During these four year period, this program focused on an improved process which is based on our close-coupled two stage liquefaction of coal, or CTSL process as we call it. This process uses two catalytic reactors in stages as opposed to the thermal catalytic process used by many others around the world.

I am happy to say that during this four-year period, HRI made major breakthroughs in this technology. Specifically, we increased oil yield from slightly over three barrels of oil per ton of coal to over five barrels of oil per ton of coal, or a 50 percent overall increase in liquid yield.

What is more astounding is that the selectivity to transportation fuels, and the quality of these fuels did not suffer. On the contrary, we were able to produce greater quantities of material in the gasoline and diesel range while cutting the sulfur and nitrogen content of these fuels by 50 percent compared to the results demonstrated during the H-COAL era.

Product upgrading studies by Chevron have confirmed that our products make excellent-high density jet fuels that could be of potential interest to the Air Force. More recently, an independent study by the MITRE Corporation and sponsored by the Department of Energy, confirmed that the CTSL technology is the lowest cost in the field.

In direct liquefaction at least, the United States Government has been able to maintain its technology advantage in the international community in spite of the huge cutbacks in research and development funding in recent years. In fact, offshoots from the CTSL program are already benefitting new U.S. technologies that are meeting the acid rain challenge for cleaning up high-sulfur and nitrogen fuels in acceptable and economic fashion.

One such offshoot is HRI's two-stage coal oil co-processing technology which has been selected by Ohio Ontario Clean Fuels for demonstration in Warren, Ohio, and funding by DOE under the Clean Coal Technology Program in private industry.

The continued work in this field, of course, depends upon the wise decisions of this Subcommittee, others in Congress, the Department of Energy and the Administration. We have been lucky so far operating on this reduced budget level, but much remains to be done.

We at HRI are at a critical stage where the CTSL technology is ready for scale-up to a PDU stage, but DOE may lack the funds for anything more than additional bench scale work this year while its proposed funding for fiscal year 1989 probably would leave nothing for this program.

What we actually need to advance this program is funding at a $4 million per year over the next four years. Halting this program at this point would be a terrible blow to our nation's fossil energy program. Support from yourselves for this program will ensure that the United States maintains its position at the leading edge in direct liquefaction.

Thank you, Mr. Chairman.

[The prepared statement of Dr. Wisdom follows:]

STATEMENT OF

LAWRENCE I. WISDOM
EXECUTIVE VICE PRESIDENT
HYDROCARBON RESEARCH, INC.

TO THE SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT

HOUSE COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY

MARCH 3, 1988

MADAM CHAIRMAN AND MEMBERS OF THE SUBCOMMITTEE, HYDROCARBON RESEARCH, INC. (HRI) APPRECIATES YOUR INVITATION TO TESTIFY TODAY ON THE DEPARTMENT OF ENERGY'S FOSSIL RESEARCH AND DEVELOPMENT BUDGET REQUEST. AS YOU KNOW, HRI HAS PLAYED A KEY ROLE IN THE RESEARCH AND DEVELOPMENT OF TECHNOLOGIES THAT CONVERT OUR DOMESTIC ENERGY RESOURCES INTO CLEAN FUELS.

FORTY-FIVE YEARS AGO A GROUP OF SCIENTISTS AND ENGINEERS WHO HAD BEEN PART OF THE MANHATTAN PROJECT FORMED HRI TO DEVELOP A PROCESS FOR CONVERTING NATURAL GAS, WHICH THE NATION HAD IN ABUNDANCE, TO GASOLINE, WHICH WAS SUFFERING FROM WAR TIME SHORTAGES. OUR HISTORY DURING THE INTERVENING YEARS HAS BEEN A FASCINATING ONE INVOLVING MANY TECHNOLOGIES WHICH HAVE BEEN DEPLOYED THROUGHOUT THE WORLD. HOWEVER, NOTHING HAS BEEN MORE EXCITING THAN OUR WORK IN DEVELOPING PROCESSES TO CONVERT AMERICA'S LARGEST ENERGY RESOURCE, COAL, INTO CLEAN DISTILLATE FUELS.

HRI OWNS NO PRODUCTION FACILITIES OF ANY KIND. IT IS A PURE RESEARCH AND DEVELOPMENT ORGANIZATION SERVING THE NATION THROUGH THE DEPARTMENT OF ENERGY AND THE HYDROCARBON INDUSTRY. TECHNOLOGICAL ADVANCES MADE THROUGH GOVERNMENT SPONSORED RESEARCH AT HRI CAN LEAD DIRECTLY TO COMMERCIALIZATION BY PRIVATE INDUSTRY, SOMETHING THAT IS NOT ALWAYS THE CASE WITH GOVERNMENT SPONSORED RESEARCH.

ALSO, WE ARE PROUD OF THE ECONOMIES THAT WE HAVE BEEN ABLE TO ACHIEVE IN CARRYING OUT THIS GOVERNMENT RESEARCH AT EITHER THE BENCH SCALE OR PROCESS DEVELOPMENT UNIT (PDU) SCALE THUS PROVIDING THE GOVERNMENT WITH A LOT OF "BANG" FOR ITS BUCKS.

LATER I WILL COMMENT ON THE EMPHASIS WHICH WE AT HRI BELIEVE SHOULD BE GIVEN TO FOSSIL ENERGY RESEARCH AND DEVELOPMENT IN THE CONTEXT OF TODAY'S SEVERE BUDGET RESTRAINTS, THE EXCITING PROGRESS BEING MADE TODAY AT HRI IN THE DIRECT LIQUEFACTION OF COAL, AND OUR RECOMMENDATIONS FOR FUTURE RESEARCH AND DEVELOPMENT IN THIS FIELD.

IT IS A SAD COMMENTARY TODAY THAT THE UNITED STATES IS WITHOUT AN ADEQUATE LONG-TERM ENERGY POLICY FOR THE LACK OF A SHORT-TERM ENERGY CRISIS IN THE FORM OF LONG LINES AT THE GAS PUMP. UNFORTUNATELY THERE IS A CRISIS; DOMESTIC OIL PRODUCTION FELL 4.4% LAST YEAR WHILE OIL IMPORTS CONTINUE TO RISE ABOVE 40% OF DOMESTIC

CONSUMPTION. ENERGY POLICY CONTRAINS FOREIGN POLICY NOW. UNITED STATES NAVAL FORCES IN THE PERSIAN GULF PROVE THAT. THE CHOICES AVAILABLE TO THE UNITED STATES TODAY WILL BE FURTHER CONSTRAINED AS DEPENDENCE CLIMBS PAST 50% SOMETIME IN THE 1990's. THE UNITED STATES DOESN'T LACK OPTIONS. WHAT IT LACKS IS A SENSE OF URGENCY ABOUT EXERCISING THEM. IF IT DOESN'T DEVELOP THAT SENSE SOON, DEPENDENCY ON FOREIGN OIL WILL MAKE THE UNITED STATES FOREIGN POLICY THE MORAL EQUIVALENT OF AN ARMY WITHOUT FUEL. IT WE CAN SPEND MILLIONS OF U.S. DOLLARS TO PROTECT FOREIGN OIL EXPORTS FROM THE PERSIAN GULF, THEN CERTAINLY WE CAN DO MORE IN CONVERTING OUR DOMESTIC FOSSIL ENERGY RESERVES INTO CLEAN TRANSPORTATION FUELS, THEREBY STRENGTHENING OUR FOREIGN POLICY OPTIONS.

I COME BEFORE YOU TODAY AS A SOLID SUPPORTER OF A BALANCED BUDGET, AND THAT MEANS BUDGET RESTRAINTS. I AM NOT HERE TO PLEAD FOR NEW HUNDREDS OF MILLIONS OR BILLIONS FOR COMMERCIAL TECHNOLOGY DEMONSTRATION, HELPFUL AS THEY MIGHT BE. THE HUGE FEDERAL DEFICITS OF RECENT YEARS RULE THAT OUT. BUT IT CLEARLY IS IN THE INTEREST OF THE AMERICAN PEOPLE TO PUT TOGETHER A RESPONSIBLE, BALANCED PROGRAM THAT ALLOWS FOR FUNDAMENTAL FOSSIL ENERGY RESEARCH AS WELL AS CONTINUED DEVELOPMENT OF THE NATION'S MOST PROMISING TECHNOLOGIES. I REGRET TO SAY THAT WE AT HRI DO NOT BELIEVE THE FOSSIL R&D BUDGET SUBMITTED BY THE ADMINISTRATION FOR DOE COMES CLOSE TO MEETING THAT NEED.

AS THIS SUBCOMMITTEE KNOWS, HRI OVER THE YEARS HAS BEEN A LEADER IN THE FIELD OF DIRECT LIQUEFACTION OF COAL. DURING THE LATE 70's AND EARLY 80's, THE UNITED STATES DEPARTMENT OF ENERGY FUNDED THE CONSTRUCTION AND OPERATION OF THREE (3) COAL LIQUEFACTION TECHNOLOGIES: HRI'S H-COAL® PROCESS, EXXON'S EDS PROCESS, AND GULF'S SRC PROCESS. DURING THIS TIME PERIOD, HRI CONFIRMED THE SCALE-UP OF THE H-COAL® PROCESS AND OBTAINED VALUABLE OPERATIONS AND MAINTENANCE INFORMATION APPLICABLE TO COMMERCIAL OPERATIONS. THE LARGE SCALE H-COAL® PILOT PLANT AT CATLETTSBURG, KENTUCKY, CLOSED DOWN IN 1982 AFTER CONFIRMING OIL YIELDS OF 3.3 BARRELS PER TON PRODUCED WHICH HAD BEEN DEMONSTRATED IN HRI'S BENCH AND PROCESS DEVELOPMENT UNITS. THEN IN 1983 DOE AWARDED HRI A TWO YEAR FOLLOW-ON CONTRACT TO PURSUE THE RESEARCH AND DEVELOPMENT OF DIRECT COAL LIQUEFACTION. IN 1985 DOE APPROVED A TWO YEAR FOLLOW-ON TO THAT PROGRAM WHICH HAS BEEN EXTENDED TO THE PRESENT.

THIS PROGRAM FOCUSED ON AN IMPROVED PROCESS WHICH IS BASED ON THE CLOSE-COUPLED TWO-STAGE LIQUEFACTION OF COAL (CTSL) IN EBULLATED-BED REACTORS. A SIMPLIFIED FLOW SCHEME FOR HRI's CTSL PROCESS IS SHOWN IN FIGURE 4. GENERAL FEATURES OF THE PROCESS ARE LISTED IN TABLE 1. AS SHOWN IN THIS TABLE, THE CTSL PROCESS USES TWO CLOSE-COUPLED CATALYTIC REACTORS AS OPPOSED TO THE THERMAL/CATALYTIC REACTORS USED BY OTHER PROCESSES. THE PRESENCE

OF CATALYST IN THE FIRST-STAGE REACTOR IS INTENDED TO PROMOTE THE TRANSFER OF HYDROGEN TO THE REACTING COAL AND STABILIZE THE FIRST-STAGE LIQUEFACTION PRODUCTS, THUS PREVENTING ANY RETROGRADE REACTIONS. THE SECOND-STAGE CATALYTIC REACTOR COMPLETES COAL CONVERSION AND ALSO PROMOTES CONVERSION OF THE RESIDUUM FRACTION TO DISTILLATE PRODUCTS.

I AM HAPPY TO SAY THAT DURING THIS FOUR YEAR PERIOD HRI MADE MAJOR BREAKTHROUGHS IN THIS TECHNOLOGY. SPECIFICALLY, HRI INCREASED OIL YIELDS FROM 3.3 BARRELS PER TON TO OVER 5 BARRELS PER TON OF COAL, OR A 50% OVERALL INCREASE IN LIQUID YIELD. WHAT IS MORE AMAZING IS THAT THE SELECTIVITY TO TRANSPORTATION FUELS AND THE QUALITIES OF THESE FUELS DID NOT SUFFER; ON THE CONTRARY, WE WERE ABLE TO PRODUCE GREATER QUANTITIES OF MATERIAL IN THE GASOLINE AND DIESEL RANGE WHILE CUTTING THE SULFUR AND NITROGEN CONTENT OF THESE FUELS BY 50%, COMPARED TO THE RESULTS DEMONSTRATED DURING THE H-COAL® ERA. PRODUCT UPGRADING STUDIES BY CHEVRON HAVE SHOWN THAT CTSL PRODUCTS CAN MAKE EXCELLENT HIGH DENSITY JET FUELS OF INTEREST TO THE AIR FORCE.

AN INDEPENDENT STUDY BY THE MITRE CORPORATION, AND SPONSORED BY THE DEPARTMENT OF ENERGY, CONFIRMED HRI'S IMPROVED COAL LIQUEFACTION TECHNOLOGY AS THE LOWEST COST IN THE FIELD. A COMPARISON OF THIS PROCESS AGAINST LEADERS IN THE UNITED STATES

INDUSTRY IS SHOWN IN FIGURES 1, 2 AND 3. FIGURE 1 SHOWS THE OVERALL TECHNICAL PERFORMANCE SUMMARY FOR THE PROCESSES ON BOTH ILLINOIS NO. 6 COAL AND WYOMING COAL. THE ECONOMIC COMPARISON ON EACH OF THOSE COALS ARE SHOWN RESPECTIVELY IN FIGURES 2 AND 3. MITRE BASED THEIR STUDY ON HRI'S 1983-1985 CTSL PROGRAM. IN THE LAST TWO YEARS WE HAVE CONTINUED TO ADVANCE THE CTSL PROCESS THROUGH FURTHER OPTIMIZATION. AN OVERVIEW OF THESE ACCOMPLISHMENTS IS SHOWN BELOW FOR THE ILLINOIS NO. 6 COAL:

	H-COAL® PROCESS	THERMAL/CATALYTIC TWO-STAGE LIQUEFACTION	CTSL PROCESS	
YIELDS, W % M.A.F. COAL			1983-85*	1985-87
Gas (C_1-C_3)	11	8	7	8
Product (C_4-975°F)	51	61	67	78
Residuum and Unconverted Coal	27	22	10	5
LIQUID PRODUCT (BBL/TON M.A.F. COAL)	**3.3**	**3.9**	**4.1**	**5.0**
PRODUCT QUALITY				
°API	26	25	24	28
End Point, °F	975	975	975	750
Nitrogen, W %	0.49	0.34	0.33	0.25
Sulfur, W %	0.02	0.08	0.05	0.01

*Based on Mitre Study, Run 227-20-15.

THE TWENTY-TWO PERCENT INCREASE IN YIELD AND CORRESPONDING ECONOMIC ENHANCEMENT INCURRED DURING THE LAST TWO YEARS WILL SURELY PLACE THE CTSL TECHNOLOGY AT THE LEADING EDGE OF DIRECT COAL LIQUEFACTION TECHNOLOGIES IN THE WORLD TODAY.

THIS PROCESS IS SIMILAR IN MANY RESPECTS TO THE ONLY COMMERCIAL TWO-STAGE EBULLATED-BED PROCESS OPERATING TODAY AT TEXACO'S CONVENT, LOUISIANA REFINERY TO PROCESS PETROLEUM RESIDUE AND LICENSED BY HRI. AS A RESULT OF IMPROVEMENTS MADE UNDER THE CTSL PROGRAM, CRITICAL FEEDBACK FROM COMMERCIAL OPERATIONS ON UPGRADING PETROLEUM RESIDUUM AND HRI'S BACKGROUND IN PROCESSING COAL AND OIL TOGETHER, HRI WAS ABLE TO DEVELOP A SUPERIOR COAL/OIL CO-PROCESSING TECHNOLOGY. THIS TECHNOLOGY HAS BEEN SELECTED BY OHIO ONTARIO CLEAN FUELS FOR DEMONSTRATION IN WARREN, OHIO, AND FUNDED BY DOE UNDER THE CLEAN COAL TECHNOLOGY PROGRAM AND PRIVATE INDUSTRY.

AS WE CAN SEE, IN DIRECT LIQUEFACTION, AT LEAST, THE UNITED STATES GOVERNMENT HAS BEEN ABLE TO MAINTAIN ITS TECHNOLOGY ADVANTAGE IN THE INTERNATIONAL COMMUNITY IN SPITE OF THE HUGE CUT BACKS IN RESEARCH AND DEVELOPMENT FUNDING IN RECENT YEARS. IN FACT, OFFSHOOTS FROM THE CTSL PROGRAM ARE ALREADY BENEFITTING NEW U.S. TECHNOLOGIES THAT ARE MEETING THE ACID RAIN CHALLENGE FOR CLEANING UP HIGH SULFUR AND NITROGEN FUELS IN AN ACCEPTABLE AND ECONOMIC FASHION. WHETHER THE UNITED STATES WILL CONTINUE IN THE LEAD, HOWEVER, DEPENDS ON THE WISE DECISIONS OF THIS SUBCOMMITTEE, OTHERS IN THE CONGRESS, THE DEPARTMENT OF ENERGY AND THE ADMINISTRATION. WE HAVE BEEN LUCKY SO FAR, OPERATING ON THIS REDUCED LEVEL, BUT MUCH REMAINS TO BE DONE. WE ARE AT A CRITICAL STAGE NOW, WHERE THE CTSL TECHNOLOGY IS READY FOR SCALE-UP TO THE PDU STAGE BUT DOE MAY LACK THE FUNDS FOR ANYTHING MORE THAN ADDITIONAL BENCH-SCALE WORK THIS YEAR, WHILE ITS PROPOSED FUNDING FOR FY 1989 PROBABLY WOULD LEAVE NOTHING AT ALL FOR THIS PROGRAM. WHAT WE ACTUALLY NEED TO ADVANCE THIS TO THE PDU STAGE IS FUNDING AT $4 MILLION PER YEAR OVER THE NEXT FOUR YEARS.

HALTING THE PROGRAM AT THIS POINT WOULD BE A TERRIBLE BLOW TO OUR NATION'S FOSSIL ENERGY PROGRAM. WHILE WE HAVE MADE GREAT STRIDES IN THE LAST FOUR YEARS, PDU SCALE UP IS REQUIRED IF WE ARE GOING TO SUCCEED IN REDUCING INVESTMENT AND IN OPERATING COST WHILE MAINTAINING HIGH LIQUID YIELDS AT AN ACCEPTABLE QUALITY. FURTHERMORE, COALS FROM ILLINOIS, KENTUCKY, OHIO, PENNSYLVANIA, WEST VIRGINIA, TEXAS AND WYOMING ARE ALL BEING CONSIDERED FOR TESTING. FROM THE PROCESS DEVELOPMENT UNIT (PDU) STAGE, DIRECT COAL LIQUEFACTION CAN BE READILY SCALED UP TO THE COMMERCIAL PLANT LEVEL. AT THIS POINT THE TECHNOLOGY WILL BE READY TO PROVIDE ENVIRONMENTALLY CLEAN TRANSPORTATION AND UTILITY FUELS FROM A STRATEGIC DOMESTIC RESOURCE.

THE CURRENT CTSL PROGRAM WITH THE DEPARTMENT OF ENERGY ENDS THIS MONTH. THE FOLLOW-ON PROGRAM PROPOSED BY HRI WOULD CALL FOR THE INVESTIGATION OF:

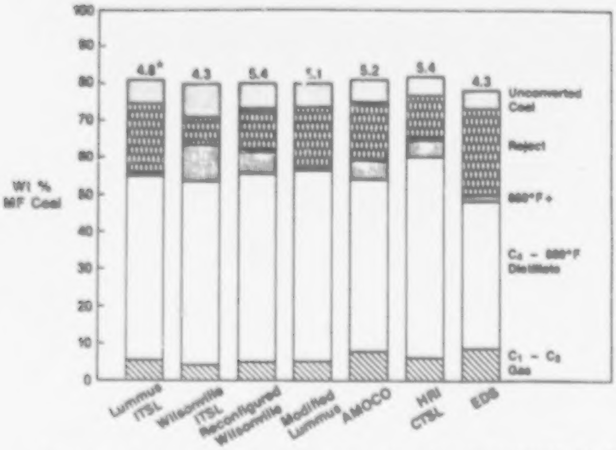
- USE OF HIGH SULFUR COALS.
- EVALUATION OF ALTERNATE LOW RANK COALS.
- ON-LINE PRODUCT UPGRADING.
- INTEGRATION OF AN ASH REJECTION STEP.
- PROCESS IMPROVEMENT AND COST REDUCTION STUDIES.
- DEMONSTRATION AND OPTIMIZATION IN A TWO-STAGE PDU TO DEVELOP A SCALE-UP DATA BASE, CONFIRM OPERABILITY AND EVALUATE FLUID DYNAMIC ISSUES.
- PRODUCING SUFFICIENT QUANTITIES OF CLEAN DISTILLATE FUELS FOR TESTING BY THE DEPARTMENT OF DEFENSE AND OTHERS.

ALTHOUGH THE PROPOSED PROGRAM FOCUSES EXCLUSIVELY ON THE PROCESSING OF COAL, HRI IS ABLE TO UTILIZE ITS EXTENSIVE DATA BASE ON OVER FIFTY (50) CRUDES IT HAS PROCESSED FROM AROUND THE WORLD TO ESTIMATE APPROXIMATE YIELDS AND PRODUCT QUALITIES FOR THE CO-PROCESSING OF COAL AND OIL, AS WELL. SUPPORT FROM CONGRESS FOR THIS PROGRAM WILL ENSURE THAT THE UNITED STATES MAINTAINS ITS POSITION AT THE LEADING EDGE IN DIRECT LIQUEFACTION.

THANK YOU

FIGURE 1: TECHNICAL PERFORMANCE SUMMARY

ILLINOIS NO. 6 COAL



*These numbers are hydrogen consumption in wt. percent MF Coal.

WYOMING COAL

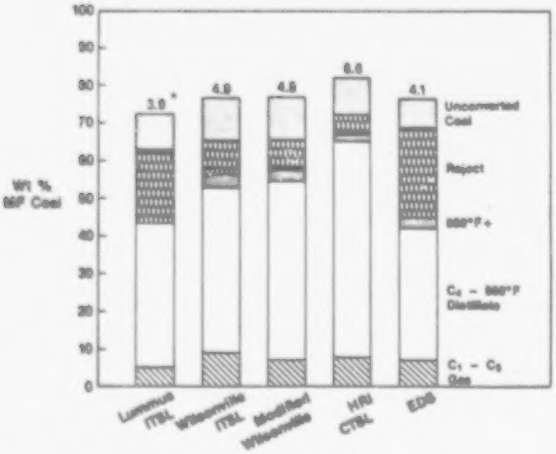


FIGURE 2

Economic Comparisons of Illinois No. 6 Coal Plants

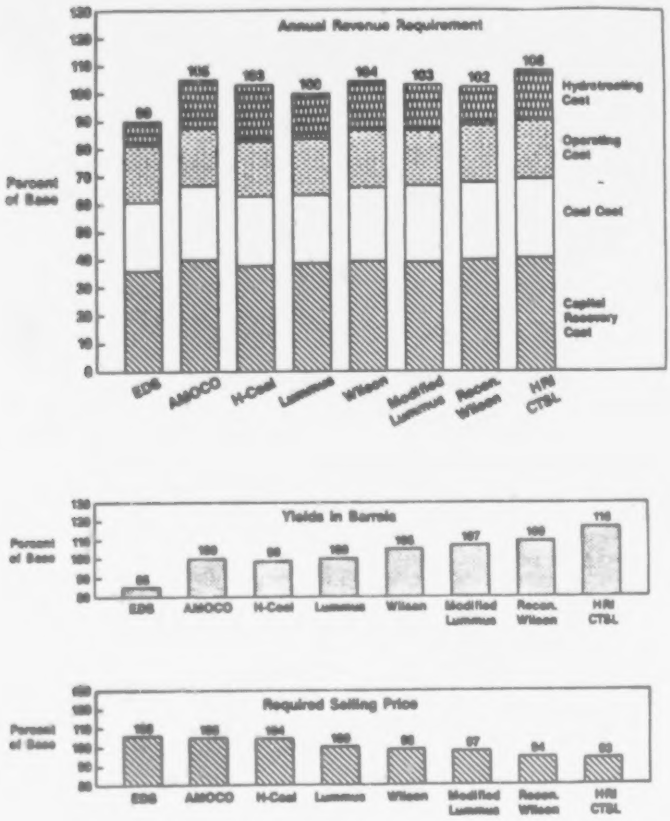


FIGURE 3

Economic Comparisons of Wyoming Coal Plants

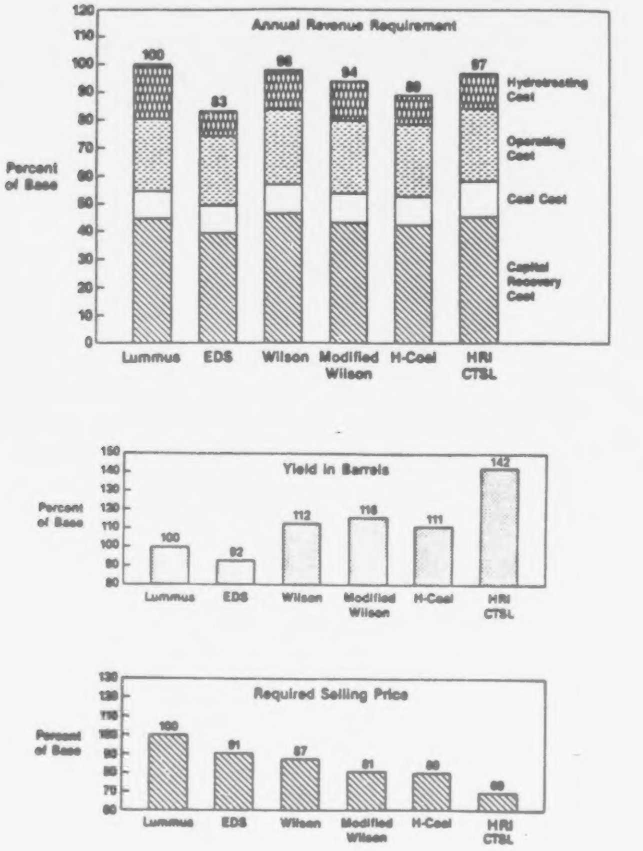


Figure 4

HRI EBULLATING-BED
CATALYTIC TWO-STAGE COAL LIQUEFACTION (CTSL) PROCESS
SIMPLIFIED FLOW PLAN

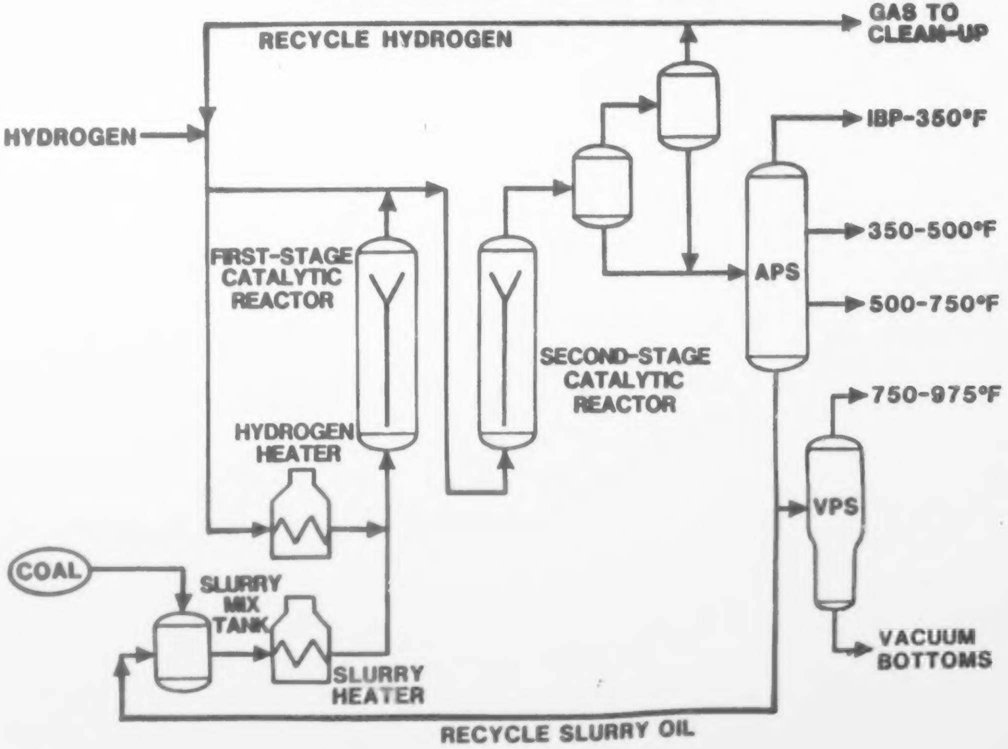

RECYCLE HYDROGEN
GAS TO CLEAN-UP
HYDROGEN
IBP-350°F
350-500°F
500-750°F
APS
FIRST-STAGE CATALYTIC REACTOR
SECOND-STAGE CATALYTIC REACTOR
HYDROGEN HEATER
750-975°F
VPS
COAL
SLURRY MIX TANK
SLURRY HEATER
VACUUM BOTTOMS
RECYCLE SLURRY OIL

TABLE 1

HRI'S CATALYTIC TWO-STAGE LIQUEFACTION PROCESS: FEATURES AND FUNCTIONS

General Features

- Two directly-coupled catalytic reactors
- Proven ebullated-bed technology
- Low-temperature, first-stage operation in the presence of hydrogenation catalyst
- Second-stage operating conditions similar to H-Coal process

Intended Reactor Functions

- First-stage Reactor

  --Initial coal conversion
  --Hydrogen transfer to reacting coal
  --Solvent residuum hydrogenation
  --Stabilization/upgrading primary liquefaction products

- Second-stage Reactor

  --Complete coal conversion
  --Residuum conversion to distillate products
  --Heteroatom removal
  --Prevent dehydrogenation of products

Mr. BOUCHER. Thank you, Dr. Wisdom. Dr. Squires.

STATEMENT OF DR. THOMAS G. SQUIRES, EXECUTIVE DIRECTOR, ASSOCIATED WESTERN UNIVERSITIES; CHAIRMAN, FUEL CHEMISTRY DIVISION, AMERICAN CHEMICAL SOCIETY, WASHINGTON, DC, ON BEHALF OF THE AMERICAN CHEMICAL SOCIETY

Dr. SQUIRES. Mr. Chairman and Members of the Subcommittee, my name is Thomas G. Squires. I am an Executive Director of Associated Western Universities, and Chairman of the Fuel Chemistry Division of American Chemical Society. This division is comprised of over 1,000 chemists and engineers, whose primary interest is in R&D in alternative fossil fuels.

I speak to you this morning with the full authorization of the ACS Board of Directors. The American Chemical Society appreciates the opportunity to present its views on DOE's fiscal year 1989 budget request for fossil energy. In presenting these views, we have identified needs and opportunities in fossil energy R&D, especially in basic research. We have also made specific recommendations concerning funding levels, areas of research that should be emphasized, and implementation and management of the programs.

The dangerous situation posed by external control of crude oil supplies must be offset. Conversion of the abundant coal reserves in the United States to fuels and chemicals offers us a solution. In order to accomplish this, the Federal Government must invest adequately and long term in basic coal research conducted at universities and other research facilities across this nation.

In addition, we must have increased Government support in order to maintain a viable coal research community. Let me give you a personal example about this. I became seriously interested in coal research in 1977 and undertook a program in coal chemistry at the Ames Laboratory. By 1980, my research had 10 members and four of these were Ph.D.'s In 1986, when I left the Ames Laboratory to take my present position, I had two scientists working in coal research with prospects for only one in 1987.

It is indeed unfortunate that cutbacks are being proposed at a time when the opportunities for advancement have never been greater. Today, new spectroscopic techniques, chemical procedures and theoretical understandings are available to probe the structure and reactions of noncrystalline solids such as coal. New diagnostic tools and computer modeling techniques are being advanced for accurate determination of process behavior. The potential exists for rapidly developing new knowledge. However, to utilize these resources properly we need stable, continuous, long-range R&D programs. The present budget in fact, cuts back in this area of research.

Therefore, the American Chemical Society strongly recommends that advanced coal research programs should be increased by 10 percent to $44.8 million from the fiscal year 1988 funding level of $40.7 million; the Clean Coal Technology Program should be taxed 10 percent per year to fund fundamental coal research. For fiscal year 1989, this would add $52.5 million for basic coal research. The combined total support for advanced coal research programs in fiscal year 1989 of $97.2 million should be sustained over the next five years, fiscal year 1990 to 1994, so that significant progress can be made in clean use of coal.

In addition, to ensure the most efficient use of this research investment, the ACS strongly recommends a competitive, merit-based, peer review process as the primary mechanism for the selection as well as the evaluation of research projects. This should apply equally to in-house research at DOE Laboratories and Energy Technology Centers, as well as externally contracted research at universities and other non-DOE laboratories.

The ultimate objective should be to expand the use of coal while reducing pollution. The goal of the research program must be a sound foundation of understanding in coal structure and chemical and physical behavior to permit development of novel, more efficient processes and reliable, predictive modeling of coal conversion.

Thank you for this opportunity to speak to this Subcommittee.

[The prepared statement of Dr. Squires follows:]

STATEMENT
of the
American Chemical Society

STATEMENT

of

DR. THOMAS G. SQUIRES

on behalf of the

AMERICAN CHEMICAL SOCIETY

to the

SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT

COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY

U.S. HOUSE OF REPRESENTATIVES

on the

DEPARTMENT OF ENERGY FOSSIL R&D FY 1989 AUTHORIZATION

THURSDAY, MARCH 3, 1988

American Chemical Society • 1155 Sixteenth St., N.W. • Washington, D.C. 20036 • (202) 872-4479

Madam Chairman and Members of the Subcommittee:

My name is Thomas G. Squires. I am the Chairman of the Fuel Chemistry Division of the American Chemical Society. The Division is comprised of over 1,000 chemists and engineers whose primary interest is alternative fossil fuel research and development. I appear before you today with the authorization of the Society's Board of Directors to present the ACS views on federal support of coal research and development.

Coal reserves in our country represent a substantial, but inadequately utilized resource. Development of efficient methods for converting these reserves to fuels and chemicals constitutes a viable means of offsetting the danger to the Nation posed by external control of crude oil supplies. Such an option is not without cost; exploitation of this opportunity will require a stable, adequately supported research climate in which to foster the development of the needed technology.

An often used "buzzphrase" nowadays is "economic competitiveness." Yet it is very clear that, in the long run, the United States cannot be economically competitive without being scientifically and technologically competitive. For example, while the overall U.S. trade balance has plummeted from a surplus of slightly over $1 billion in 1973 to a deficit of more than $150 billion in 1986, the technology-intensive U.S. chemical industry has maintained a consistently positive balance of trade during this period, with an average surplus of approximately $7.5 billion.

Chemistry and chemical engineering have had the advantage of a stable research climate over many decades, supported by both government and the chemical industry. Such long-term support of chemical research has ensured the competitiveness of the industry. Similarly, a well-planned, long-term commitment to coal science and technology will ensure adequate utilization of the Nation's most abundant domestic energy resource.

A true commitment to advanced coal research and technology development requires that each year a substantial portion of monies appropriated for Fossil Energy Coal Research and Development be used to support basic research in coal science and engineering at universities and other research facilities throughout the nation.

Specifically, for FY 1989, the American Chemical Society recommends that the Advanced Research Programs be increased by 10 percent from the FY 1988 funding level of $40.7 million to $44.8 million. The Society recommends that the remainder of the Fossil Energy budget be restored to the FY 1988 appropriated level. (The accompanying Appendix gives a budgetary history for Advanced Coal Research Programs--Advanced Research and Technology Development, Coal Liquifaction Advanced Research, Surface Coal Gasification Advanced Research, Control Technology and Coal Preparation Advanced Research, Combustion Systems Advanced Research, and Fuel Cells Advanced Research)

The ACS also recommends that 10 percent of the Clean Coal Technology Program be set aside for basic research in this area. For FY 1989 this would correspond to $52.5 million. This action is necessary because many of the mechanisms which generate pollutants from the combustion of coal are not understood. Without this knowledge, it is impossible to develop adequate control strategies.

The American Chemical Society recommends that the total level of support for Advanced Coal Research Programs in FY 1989 be $97.2 million. Significant progress could be made in clean utilization of coal if this level of funding is sustained over the next five years. The Society believes that research funded under these these programs should incorporate a strong peer review component, both in reviewing proposed research and in evaluating research accomplishments.

The ACS also believes that priorities should be established for funding basic, long-range coal research and offers the following comments and recommendations:

- Coal should be the cornerstone of the alternative fossil fuel strategy with the ultimate objective of expanding its utilization while reducing pollution.
- The goal of the research program must be a sound foundation of understanding in coal structure and chemical and physical behavior to permit development of novel, more efficient processes and reliable predictive modeling of coal conversion.
- Research components in CLEAN COAL APPLICATIONS in need of increased funding are:

  Mechanisms of Coal Cleaning
  Waste Management
  Chemistry of Polluting Species
  Combustion Modification
  Ash Formation and Properties

- Research components in COAL STRUCTURE AND REACTIVITY in need of increased funding are:

  Coal Characterization
  Volatile Properties and Reactivity
  Char Formation
  Coal Physical Behavior

- Research components in PROCESS IMPROVEMENTS AND NOVEL PROCESSES in need of increased funding are:

  Mechanistic Modeling
  Diagnostics
  Catalysis
  Coal/Solvent Chemistry
  Novel Liquefaction Methods
  Chemicals from Coal

- Increased government support to maintain a viable coal research community is urgent in view of the continuing reduction in industrial support since the early 1980's.

The American Chemical Society appreciates the opportunity to express its views on this issue. The costs of implementing these recommendations would be small compared to the potential benefits derived in helping to ensure a stable, long-range energy supply in the U.S. and in reducing the Nation's vulnerability to the uncertainties in foreign oil supplies.

March 3, 1988

APPENDIX

Federal Support for Advanced Coal Research Programs (a)

(Dollars in Thousands)

	Coal Liquefaction Advanced Research	Surface Coal Gasification Advanced Research	Control Technology & Coal Preparation Advanced Research	Combustion Systems Advanced Research	Fuel Cells Advanced Research	Advanced Research & Technology Development	TOTAL
1981						$58,383	$58,383
1982						51,936	51,936
1983						31,650	31,650
1984						38,996	38,996
1985	$5,511	$3,364				30,804	39,679
1986(b)	5,157	3,379				33,849	42,385
1987	4,470	2,806	$1,139	$3,248	$1,350	26,630	39,643
1988	6,132	2,698	2,042	3,351	1,547	24,937	40,707
1989(c)	3,241	684	1,774	2,092	997	21,410	30,198

a. Until 1986, Coal Liquefaction Advanced Research and Surface Coal Gasification Advanced Research were funded under Advanced Research and Technology Development as the Processes subprogram. Part of the Direct Utilization subprogram under AR&TD was transferred to Advanced Research within Control Technology and Coal Preparation, Combustion Systems, and Fuel Cells to comply with FY 1988 Congressional direction.

b. Enacted budget, after 4.3% reduction due to Gramm-Rudman-Hollings deficit reduction legislation.

c. Administration's Budget Request.

Source: Budget Justification Books for the Department of Energy.

PANEL 2 DISCUSSION

Mr. BOUCHER. Thank you, Dr. Squires. Mr. Coates, let me begin the questions with you. The Department of Energy, as you know, has not requested any funding for MHD for the upcoming fiscal year.

They say that in an era of fiscal restraint, there simply isn't enough money to complete this program. They are estimating that the cost of completion to the proof of concept would be $172 million. I think you mentioned the figure of $187 million by 1992. I guess it would help if you sort of made a case for us as to why we should put the money back in.

Let me just ask a couple of specific questions that would give us some idea of where this project is and where it is going. When do you think we would be completed with our funding of this, when you could get it to proof of concept and have it ready for commercial utilization?

Mr. COATES. If you recall, Mr. Chairman, a couple of years ago the Department of Energy held very extensive public hearings, in which all the experts in the MHD field representing Westinghouse and AVCO and TRW, Babcox and Wilcox, anyone who had anything to do with MHD.

We reviewed very carefully, the technology, the state of the components, the economics and the environmental impact. On the conclusion of that, the Department put together what they called a redirected plan which was submitted very formally to the Chairman of this Committee.

Late last year, they let four major contracts to conduct a proof-of-concept program which was laid down in that document as put together with industry. That is described, by the way, in my testimony.

If those programs are funded—and I don't believe their numbers—but if they are funded to the way that we are saying and those numbers put together by the MHD Industrial Forum and all those experts that I mentioned, it will take about until 1992. In 1992 we will then be able to proceed with the retrofit.

If, not just in this Administration but in other Administrations, it followed the dictates of Congress and got down to work and put together the plan, we would have had a retrofit today instead of watching the Soviets do it.

Specifically then, if it is funded by 1992—if for whatever reasons. If the dollars become less it won't be funded. If I may, one added point. Dr. Wisdom made an excellent point about international relations. The Middle East is a very unstable area. For the United States—for the Department of Energy to ask for so little money for fossil energy which represents our most important source of fuel, in my judgment it is a disgrace.

One final point. I've been—my associates out there may not like this. I know that the Department of Energy and the evidence is here, has put together MHD plans. The problem is, and everyone else knows, it's OMB who is calling the shots. As a taxpayer, I find it objectionable to have Assistant Secretaries and Secretaries who are confirmed, who come up here and show you their qualifications and capabilities, who have to come up here every year and make their case to you, are overruled by a bunch of unnamed, unconfirmed people in OMB.

That's why we don't have an MHD program and that's why we don't have any energy policy. That's why you have these ridiculous dollars which are stated here. I hope that I am getting across my frustration.

Mr. BOUCHER. Well, you have a frustration that I think is shared by many of us from time to time in dealing with some of the unelected people you refer to. Is there any private sector money in the MHD research program today?

Mr. COATES. Yes, sir.

Mr. BOUCHER. Where is it coming from, and in what amounts?

Mr. COATES. As you recall, a couple of years ago in the Appropriations Bill, they stated that the industry would contribute 10 percent the first year and then 5 percent each additional year, which brings us up to the retrofit, at which point there will be 50 percent.

We have met the requirements as established in that legislation for 1987, and we are currently negotiating for the current year.

Mr. BOUCHER. Can you tell me what the dollar amounts are? Just take 1987 as an example year. How many private dollars were being contributed to MHD research and from what sources?

Mr. COATES. I don't have that number. I would like to answer that, if I may.

Mr. BOUCHER. It would be very helpful for us to have that answer. If you would supply it in writing, we would appreciate that.

Mr. COATES. Yes, sir. I have one other comment.

Mr. BOUCHER. I have some other questions and give you a chance to vent any further frustration that you have at the conclusion of that.

You referred to the Department of Energy's promise to provide in 1987 an MHD plan. I don't know that we have received that plan. I think you probably haven't either, or have you? If you have it, I would be very interested in knowing what it is and having it submitted to us.

Mr. COATES. The plan was submitted to the Congress in June of 1984.

Mr. BOUCHER. There was a promise by DOE, I believe in 1986, to provide an updated plan in 1987. To my knowledge, we have not received that.

Mr. COATES. No, you haven't.

Mr. BOUCHER. You haven't either, have you?

Mr. COATES. We haven't either. We keep hearing about it. Again, I suggest you ask them what OMB is doing with it.

Mr. BOUCHER. That's the problem with the unelected people. There is an arrangement between the United States and Italy for cooperation in doing MHD research. Has there been a finalization of that cooperative agreement and if so, what is the status of it and is there cooperative research occurring?

Mr. COATES. To the best of my knowledge, Mr. Chairman, the negotiations are continuing between the United States and the Italian government.

Mr. BOUCHER. Do you see any prospect for international cost sharing in MHD? I guess there's the Italian agreement. Anything else on the horizon? Is any other effort being made with other countries?

Mr. COATES. I don't know that any efforts are being made by the Government to establish those kind of arrangements, other than the conversations that we going on with the Italians. At one time there was a close working relationship between the Soviet Union and the United States, but I don't believe at that moment that it is continuing.

Mr. BOUCHER. You had mentioned that the Soviet Union is conducting this research also. How do we stand in comparison with them in terms of progress? Are they ahead of us or are we ahead of them?

Mr. COATES. The Soviet Union is currently designing and building a 500-megawatt MHD power plant. To that extent, they are well ahead of us. The first MHD demonstration was made in the United States about 20 years ago or so at AVCO. For many years, the United States was ahead of the world but then because of the lack of any kind of an energy policy, we have fallen behind.

The difference between the U.S. program and the Soviet program is that our technology is more sophisticated. But what is lacking is any focused, determined effort to go forward with a pilot plant.

Mr. BOUCHER. Why do we not have that focused determined effort? Is that the fault of the Government or is it the fault of the private sector that is contributing to the research?

Mr. COATES. I think the problem lies with a kind of malaise or philosophy in the United States that says let's not take any risks. When I was young and my former boss was coming before these Committees talking about MHD, the real purpose was to have the Government join with industry to build a pilot plant, which they called them in those days. It entailed great risk because as they used to say, if you build it and turn it on it might not work.

The philosophy is don't do anything until every component is really worked out and perfected. When you finish you have a Cadillac. My view is, you would be better off on many of these programs to go ahead and build a Model-T Ford, make it work, begin to sell it internationally and then later on worry about making Cadillacs.

Mr. BOUCHER. Would it make sense in your opinion for the United States to undertake a joint research effort with the Soviet Union in this area; do you recommend that?

Mr. COATES. I can see nothing wrong with that.

Mr. BOUCHER. Has that suggestion been made by your group to the Department of Energy in the past?

Mr. COATES. No, sir. We have never really gotten into that issue, but it's something that we can certainly consider. It just never came up.

Mr. BOUCHER. Thank you very much for your answers. Dr. Hartley, I notice that in your testimony Sandia is recommending a $25 million—I believe you call it the Coal Science Initiative—which as I read your testimony, would simply be a broad-based research and development effort involving a variety of coal technologies over a 10 year period.

I think the obvious question that is raised by that is the extent of which you may wind up duplicating some of the work that is occurring under the sponsorship of the Department of Energy.

How, if this were to be funded, could you avoid that duplication of effort and what plans would you have for coordinating your work with DOE to make sure that you are not, in fact, duplicating effort?

Dr. HARTLEY. To begin with, we have discussed this at great length with the many parts of DOE that would be involved—Headquarters people, Pittsburgh and Morgantown Energy Technology Centers. We have put together a straw-man plan. We certainly don't have a detailed research plan.

There are already collections of recommended research areas that the country needs to follow. The DOE is aware of this. The existing program takes a very small piece of that recommended list. We are aware of what is going on. We intend to expand on what is going on.

It is still a DOE program. It is still coordinated by the DOE people even though we are showing a network of activity as a team among the National Labs and universities. It is not discreet and separate from the ongoing activity. It is truly an expansion of the ongoing activity.

Mr. BOUCHER. Can you give us some idea of the kinds of technologies that you would perform research with regard to that, that are not presently covered under the DOE budget and that you feel you are better able to sponsor the research in than DOE?

Dr. HARTLEY. In the area of fundamental and new catalysts applied to liquefaction for example, there is a token effort going on the country of a few people. As Dr. Squires has referred to, there are elements of research activities around the country that involve a few people planning to grow to two or three times that. With budgets being what they are, they are down to a token effort of what they were to begin with.

Mr. BOUCHER. I guess I am just having a little trouble understanding why we should focus the supervision of broad-based research efforts outside of the Department of Energy. What advantage is gained by doing that?

Dr. HARTLEY. As you may know, the approach of a National Laboratory is to not peck away at a problem a little bit at a time. We like to have a broader responsibility and solve the problem. In today's situation with the severely reduced budgets as they are, all of us working in the field are pecking away at the problem.

I think the best way to utilize a National Laboratory is to give them a broader responsibility. We do this in virtually every area that we work in other than in fossil energy. We have a major responsibility. We work with the other Labs and with universities and with the industry to decide what to do about it.

We negotiate that with DOE people and they always have the final say. We play a role in helping to execute the program. It's faster, and I believe the accomplishments speak for the system.

Mr. BOUCHER. Thank you very much. Dr. Wisdom, the Department of Energy has proposed no funding for two liquefaction projects, the Wilsonville project and the LaPorte project. Can you give us a status report on those and tell us whether you agree with

DOE that we have gained all the knowledge that we need from those projects, or whether in your opinion some additional funding is merited?

Dr. WISDOM. That's an excellent question. Those of us at HRI have focused primarily, of course, on our own liquefaction research efforts in our laboratory, in both direct coal liquefaction and direct co-processing of coal and oil.

We followed obviously, the other direct liquefaction programs at LaPorte and at Wilsonville. The Wilsonville program, as you are probably aware, was the original Gulf solvent refined coal technology which was a thermal catalytic approach, as I mentioned earlier.

We see that program as serving the country well in its early years. I would have to say frankly today, that it has basically accomplished what it has set out to. On the LaPorte program, I'm really not qualified today to comment on that one.

Mr. BOUCHER. If you would supply to the Subcommittee a written response with respect to the LaPorte program, that would be helpful to us.

Dr. WISDOM. I would be glad to.

[The information follows:]

HRI
Hydrocarbon Research, Inc.
P.O. Box 6047
New York & Puritan Avenues
Lawrenceville, New Jersey 08648
609/394-3101 Telex: 83-1829

88/LIW/69
March 22, 1988

Congress of the United States
House of Representatives
Subcommittee on Energy Research and Development
Suite 2321, Rayburn House Office Bldg.
Washington, D.C. 20515

Attention: Marilyn Lloyd
Chairman

Re: **PUBLIC HEARINGS ON FOSSIL ENERGY BUDGET**

Dear Madam Chairman:

In response to Acting Chairman Boucher's question concerning the LaPorte program (pages 60-61, lines 1227 thru 1229 of transcript), we offer the following statement for the record:

> "The liquid phase methanol technology being demonstrated at LaPorte is winding down in 1989 and Congress should provide sufficient funds to conclude this effort. The general direct coal liquefaction budget request of $3.5 million is grossly inadequate. To keep continuity of its current programs, DOE needs $2 million over the $5.5 million appropriated in 1988 to a total of $7.5 million. However, there is an ever increasing need to diversify research beyond the current programs and we urge that the Committee seek some additional funding in coming years to accomplish this."

Once again, I thank you for the opportunity to express our views to the subcommittee.

Yours truly,

Lawrence I. Wisdom

Lawrence I. Wisdom
Executive Vice President

LIW/sb
cc: Kathryn R. Holmes
B374 RHOB

Mr. BOUCHER. Give us your estimate, if you would, of the proper level of funding for coal liquefaction; what do you think the next year's budget should contain?

Dr. WISDOM. We are looking for an increase of $2 million over the fiscal year 1988 funding level.

Mr. BOUCHER. Is that contained in your written statement?

Dr. WISDOM. No, it is not.

Mr. BOUCHER. Tell us a little bit about the specific liquefaction technologies that you would like to see DOE conducting research regarding. I know that you have one process that is called the CTSL.

Dr. WISDOM. Correct.

Mr. BOUCHER. What else? Are there other specific approaches that deserve funding?

Dr. WISDOM. We believe that there are efforts both in the fundamental area as I mentioned in my written statement as well as the continuation of several technologies being conducted today. To name two which are currently being funded by the Department of Energy—one by UOP and the other by Amoco.

We feel that there is good work being done in the field in general, and that these programs as a whole should be supported.

Mr. BOUCHER. Thank you very much. Dr. Squires, I have a couple of questions for you. You probably are aware of the Administration's recommendations with respect to the Clean Coal Technology program. The Administration is asking for new money in the amount of about $1.7 billion ostensibly for the continuation of demonstration projects.

I think there is some doubt as to whether or not we really can absorb that level of funding in pure demonstration projects. Perhaps what is intended, although not stated in that request, is that there be some Government funding for deployment of these technologies.

Does your organization have any comment on that general area? What do you think of this new funding request of $1.7 billion? What do you think in general of the goals and the current status of the clean coal technology program?

Dr. SQUIRES. I can give you some comments at this point. I would prefer to address a question like that in a written statement.

Mr. BOUCHER. We would be happy to receive that. If you have any oral comments that you would like to make, that would be useful.

Dr. SQUIRES. I think that is quite a large sum of money to absorb into any technology. I have some reservations about the state of knowledge presently in the Clean Coal Technology. This is the reason that prompted me to recommend that we set aside at least a portion of that for basic research.

For example, the mechanisms of combustion that generate the polluting species, the way that the species are transported and transformed through the atmosphere are really not well understood at this point. It seems to me that would preclude being able to develop optimum control strategies.

Mr. BOUCHER. Any additional comments that you would like to make in writing would be welcomed, and we would keep the record open for that purpose.

Just looking at the basic research program administered by the Department of Energy, are there any elements missing from that that you think should be added?

Dr. Squires. I think it is fairly well structured, especially in the area of advance research and technology. What is not assured in that area is any degree of stability from year to year, and an inadequate level of funding.

I think that the elements are covered. There have been numbers of studies from the Energy Research Advisory Board on the appropriate areas for research. I think that DOE has structured a program that is responsive to these. The funding is the yoyo that keeps going up and down.

Mr. Boucher. I certainly agree with that comment. Some certainty would obviously help. The researchers need some assurance as to what funding levels on a multi-year basis are going to be. I am particularly distressed by the Administration's recommendation for funding reductions for the upcoming fiscal year's budget.

Dr. Squires. Absolutely.

Mr. Boucher. We had an appropriated level for the current fiscal year for fossil fuels for coals of about $233 million. The Administration's recommendation for fiscal year 1989 is $101.5 million. That is a reduction of about 56 percent.

What do you think an appropriate funding level for the coal category should be for fiscal year 1989?

Dr. Squires. Again, I would like to respond to this in a written statement. I do have some comments. I referred you to my career, in that in 1980 I had a group of 10 researchers. If memory serves me, that was about $800 million for coal research in that year.

So any cuts that push it down below the $200 million level are just—that means that we are running a token program. In my written statement I recommended that we restore the fiscal year 1989 budget to at least the fiscal year 1988 levels.

[The information follows:]

Question No. 2.—We had an appropriated level for the current fiscal year for fossil fuels for coal of about $233 million. The administration's recommendation for FY 1989 is $1.15 million. That is a reduction of about 56%. What do you think is an appropriate funding level for the coal category should be for FY 1989?

TGS Response. Any appropriation below the $200 million level means that our nation will not be able to retain a cadre of professionals capable of meeting the challenges in coal science and technology. Already, many scientists and engineers have (reluctantly) abandoned the coal research and development area for other more supportive technologies. The next few years are critical years in terms of maintaining a viable manpower base for coal R&D. This is one of the main reasons that the ACS recommended restoring FY 1989 funding in this area to FY 1988 levels. I reaffirm this position and further recommend that funding levels be maintained at this level or higher over the next five years.

Mr. Boucher. Thank you very much. That concludes my questions. Mr. Smith, do you have questions?

Mr. Smith of Texas. I do not, Mr. Chairman.

Mr. Boucher. Mr. Chapman, do you have questions of this panel?

Mr. Chapman. No questions, Mr. Chairman. Thank you.

Mr. Boucher. Gentlemen, we appreciate very much your testimony. Mr. Coates, if you have any other frustrations that you would like to share with us in writing, we would be happy to hear those.

Mr. Coates. Thank you very much, Mr. Chairman.

Mr. Boucher. We will leave the record open for any additional questions that members of the panel may want to propound and for your responses thereto. We extend to you our thanks for being with us today.

[Questions and answers for the record for panel 2 follow:]

RESPONSES OF VINCENT J. COATES, JR.
MHD INDUSTRIAL FORUM

to the questions of

THE SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
U.S. HOUSE OF REPRESENTATIVES

April 15, 1988

SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
U.S. HOUSE OF REPRESENTATIVES

1. What are the most critical problems remaining to be solved in establishing the feasibility of the MHD process?

There have been no insurmountable technical problems identified in the present MHD test program. Results from the integrated topping and bottoming cycle tests conducted to date have verified that the next step in the development of MHD should be a completely integrated retrofit test at the CDIF and CFFF. While all components have been successfully tested for relatively short periods, these extended tests are required to determine durability, which is the principal problem or question to be resolved. It is the purpose of the DOE´s redirected program to resolve these issues by conducting key extended tests at the CDIF and CFFF. The results of these tests will be used to design the retrofit unit.

2. What is the basis of the claim that a coal-burning MHD power plant will have an efficiency "50% better than a conventional fossil plant?"

The Fluor study results are highly questionable for a number of reasons discussed in the attached critique. Over the years there have been numerous studies and evaluations conducted for the Government. All have shown that early, one of a kind MHD power plants wil have operating efficiencies of 42-43%, mature plants about 50% and well-developed plants about 60%. The principal definitive studies reporting these efficiencies are as follows: "Parmetric study of MHD Power Plants" (PSPEC) sponsored by NASA and conducted separately by Avco Research Laboratory and General Electric; "Conceptual Design Studies of Potential Early Commercial MHD Power Plants" (CSPEC) also funded by NASA and conducted separately by Avco Research Laboratory and General Electric; "Advanced Power Train Studies" (APT) funded by DOE and conducted separately by Westinghouse and General Electric.

To the best of our knowledge no new information has been uncovered that would justify Fluor´s downgrading the 42.6% efficiency Westinghouse reported in the APT study. This analysis was based on a very early 500 MWe MHD plant design.

In conducting its study Fluor used a very early generation MHD plant on which to analyze efficiency. All the other competing technologies evaluated by Fluor were represented by well developed mature plants. Also, it makes no sense to use a gasifier in conjunction with an MHD system since the MHD combustor provides the working gas directly.

3. What are the USSR´s intentions with regard to a coal-fired MHD facility?

Early in its MHD development program planning, the USSR decided to have a two phase program. The first phase was for the development of clean fuel-fired (natural gas) MHD. This program has progressed to a point where the USSR is in the process of constructing a 500 MWe natural gas-fired MHD power plant at the site of the Ryazan central power station.

The second phase was to address coal-fired MHD, in parallel with the gas-fired systems. The Soviets have several MHD coal-fired test facilities in operation. These include the U-25G and the U-02 coal-fired facilities for testing MHD flow trains (combustors and channels). The OPU-1000 test stand has been constructed to test heat and seed recovery portions of coal-fired MHD power plants. In addition, quoting from the International Liaison Group on MHD Electrical Power Generation 1986 Status Report dated April 1987,

> "The development and the experimental operation of large solid-fuel fired [coal-fired] MHD facilities, such as the already commisssioned M-10 Facility and the currently constructed M-25 Facility are being carried out by the Krzhizhanovskii Institute of Power Research together with the Estonian Directorate of Electrical Power Development.
>
> Series of important studies on MHD power generation, mainly for coal-fired MHD, are conducted within the framework of international cooperation among the CMEA countries, Yugoslavia and Finland, as well as India. Currently a feasibiility study is conducted to clarify the first commercial-scale power plant with a tentative power of 1,000 MW. This plant is expected [to be] a base-load plant utilizing the coal from Kuznetskii fields with the oxygen enrichment up to 37% by mass and its preheat temperature up to 650 C by a recuperative heat exchanger. The combustor is of the cyclone type with 90% slag rejection in the first stage."

For many years, the USSR has been conducting MHD generator development for military applications similar to the effort recently undertaken by the SDIO. As a result of its program the USSR has built and is currently operating four portable shortburst MHD generators with power outputs up to 50 MWe. (See Attachment 2.)

While the United States continues to lead the USSR in MHD technological sophistication, the Soviet program now leads the US overall and will continue to do so until DOE is allowed to carry out its "Redirected Program" without OMB interference.

4. What cost-sharing arrangements have been made for the MHD program?

All the basic research including the first successful demonstration of an MHD power generator was funded by Avco

Corporation, the American Electric Power Company and several other utilities. Since 1986, cost sharing has been in conformance with PL 99-190. This legislation requires the private sector to cost share 10% of the Federal MHD budget in FY-86, 20% in FY-87 and 5% per annum increases thereafter. It should be noted that MHD is the only DOE technology at its stage of development that is being cost shared and it is the only non Clean Coal technology subject to cost sharing by law.

I am pleased to inform you that the Industry met its obligations in FY-86 and while negotiations continue with the Department of Energy, we expect to meet the FY-87 requirement. Negotiations are required because of the formula set forth in PL 99-190. The law provides that industry need not meet the cost share requirement if DOE fails to maintain the "redirected program" (June 1984) schedule. Industry has fully cost shared in FY-86 and FY-87 although the major contracts implementing the redirected program were not awarded until late FY-87 and early FY-88. Industry has cost shared since 1986.

It should also be noted that the continuing DOE/OMB effort to terminate the program does little to encourage industrial leaders that DOE is a reliable partner.

5. Who is contributing to the cost sharing, and how much is being provided by each participant?

Under the provisions of PL 99-190, cost sharing is generic to the entire private sector. This is in recognition that not all of the participants in the R&D program will be involved in the commercial MHD marketplace.

The list of contributors includes AVCO, B&W, Westinghouse, Mountain States Energy, TRW, Montana Power Company, University of Tennessee Space Institute, Electric Power Research Institute. Other organizations have contributed equipment and services to contractors such as UTSI.

The determination as to allowability as a cost sharing item is made by the Department of Energy's Pittsburg Energy Research Center, and consequently we are not in a position to provide information on specific contribution amounts.

SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT

Hearing on the Department of Energy (DOE)
FY 1989 Authorization Request for Fossil Energy

Republican Member Questions for the Record
for the Hearing of March 3, 1988, for
DR. DANNY L. HARTLEY, SANDIA NATIONAL LABORATORIES

1. a. What will the Coal Science Initiative provide that is not being done now?

In recent years DOE funding for coal research has not been sufficient to take full advantage of the latest scientific capabilities and analytical methods combined in a highly-integrated, long-term, exploratory research effort. The Coal Science Initiative will change this in that it will make use of a variety of cutting-edge technologies that exist in our national labs and universities in a new approach to institutional collaboration. By teaming these institutions in a common effort with a well-defined objective, results from many diagnostic and analytical techniques will be cross correlated and interrelated to develop a complete, self-consistent picture of coal. The objective of the Coal Science Initiative is to develop a fundamental understanding of and a predictive capability for coal reactivity -- based on its properties, structure and the reaction environment -- that will be used in improved combustion and conversion technologies to expand the clean use of coal. The present DOE Coal Research Program is structured along application or end-use lines (liquefaction, gasification, combustion, etc.). In contrast, the Coal Science Initiative will focus on reactivity as the key element in developing and providing a rational scientific basis for revolutionary progress in modifying coal (by thermal, chemical, etc. treatment processes) for beneficial conversion and/or combustion.

1. b. What will the Coal Science Initiative provide that cannot be done now?

The goal of the Coal Science Initiative is to develop an expansive reservoir of coal knowledge -- centered on fundamental reactivity aspects as a function of its properties, structure and the reactivity environment -- from which coal users of the future can draw needed information. The aim is to provide data and information that can be used to design a "21st Century Coal Refinery." From a computer-based "black box" of knowledge, a potential coal user can extract appropriate technology and data that applies to the particular coal and process of interest. If we are to use coal effectively and take full advantage of the enormous size of the resource, we must advance the technology for coal use -- combustion, pretreatment, conversion to liquids and gases, and environmental protection -- to a state that is not unlike advanced petroleum refineries. The Coal Science Initiative will provide the rational scientific basis for this revolutionary concept and will go far beyond the end-use driven research of the present program.

2. You note that "Sandia National Laboratories is prepared to serve as technical integrator for DOE in this program." What are the roles of each of the other laboratories (i.e., Los Alamos National Laboratory, Lawrence Livermore National Laboratory, and Idaho National Engineering Laboratory)?

   Each laboratory will have an active part in planning the overall content of the program and in structuring the tasks. Further, because of proven abilities, stated interests and demonstrated capabilities, each laboratory can logically expect to perform tasks in the overall program. For example LANL has experience in modeling of complex reactions and processes, INEL in biological processes, LBL in catalysts and coal chemistry, LLNL in reaction chemistry and coal gasification and SNL in combustion, catalysts and conversion processes. This experience will be a key to developing and carrying out the needed, comprehensive research program.

3. What are the funding requirements, by year, to complete Phase II of the Combustion Research Facility?

The cost and obligation schedule for CRF Phase II as described in the most recent Construction Project Data Sheet submitted to DOE's Office of Energy Research is tabulated below.

Cost and Obligation Schedule: (in thousands)

Fiscal Year	Authorizations	Appropriations	Obligations	Costs
1987	$ 300	$ 300	$ 300	$ -0-
1988	4,500	4,500	4,500	2,500
1989	9,700	9,700	9,700	6,000
1990	4,400	4,400	4,400	7,100
1991	-0-	-0-	-0-	3,300

4. What are the funding requirements, by year, to construct the Geoscience Research Laboratory and Simulation Facility?

Phase I of this activity would construct the Geoscience Research Lab as the central facility in our planned Geoscience Research Park. The cost of this facility as described in the most recent Construction Project Data Sheet submitted to DOE's Office of Energy Research as a FY 89 Budget Request is tabulated below.

Cost and Obligation Schedule: (in thousands)

Fiscal Year	Authorizations	Appropriations	Obligations	Costs
1989	$1,000	$1,000	$1,000	$ 500
1990	9,000	9,000	9,000	6,000
1991	6,000	6,000	6,000	5,000
1992	3,200	3,200	3,200	4,000
1993				3,700

Construction of additional Simulation Facilities would be planned for Phase II of the park and would be configured to meet the needs of collaborative university, industry, national laboratory alliances. Estimates of these costs are not available at this time.

Why Should There be a New National Laboratory/University Coal Science Program?

Because there is a new - -

- Awareness of Energy Security and Economic Issues
- Environmental Protection Consciousness
- Generation of Technical Capability
- Approach to Institutional Collaboration
- Opportunity to prepare for expanded use of our most plentiful fossil energy resource

HRI
Hydrocarbon Research, Inc.
P.O. Box 6047
New York & Puritan Avenues
Lawrenceville, New Jersey 08648
609/394-3101 Telex: 83-1829

88/LIW/89
April 26, 1988

Marilyn Lloyd, Chairman
Subcommittee on Energy Research and Development
B-374 Rayburn House Office Building
Washington, D.C. 20515

Dear Chairman Lloyd:

In regard to your letter of March 22nd requesting additional responses to various questions, we have prepared the following:

1. WHAT IS THE PROPOSED SCHEDULE FOR THE FOLLOW-ON CLOSE-COUPLED TWO-STAGE LIQUEFACTION OF COAL (CTSL) PROGRAM, PROPOSED BY HRI?

   HRI anticipates that this program will commence during the fourth quarter of FY 1988 and continue for three (3) years. At the end of the base program there is an allowance for two (2) one-year options to continue research on this technology.

2. WHAT IS THE PROPOSED FUNDING SCHEDULE FOR THIS PROGRAM? WHAT, IF ANY, COST SHARING IS HRI WILLING TO PROVIDE?

   The funding for the three year program is estimated at approximately $10 million, with an additional $6.4 million for the two one-year option periods. Although HRI has cost-shared during the last four years with DOE, we have elected not to cost-share for this program and provide to DOE full access to the data and patent rights generated therein.

3. AT WHAT COST COULD LIQUID PRODUCTS BE PRODUCED USING HRI'S CURRENT CTSL TECHNOLOGY?

   Based on studies conducted for the U.S. Department of Energy, and by Bechtel Engineering on a separate but related program, the estimated synthetic crude cost is in the range of $30-35 per barrel. The sweet syncrude has 0.01 weight % sulfur and 28° API.

We appreciate your committee's continued support and interest in our developing technology.

Sincerely yours,

Lawrence I. Wisdom/lb

Lawrence I. Wisdom
Executive Vice President

a subsidiary of
DYNALECTRON CORPORATION

American Chemical Society

1155 SIXTEENTH STREET, N.W.
WASHINGTON, D.C. 20036
Phone (202) 872-4600

April 12, 1988

The Honorable Marilyn Lloyd
Chairman
Subcommittee on Energy Research and Development
Committee on Science, Space, and Technology
U.S. House of Representatives
B-374 Rayburn House Office Building
Washington, D.C. 20515

Atten: Lottie McCaw-Daniels

Dear Madam Chairman:

The ACS Division of Fuel Chemistry is pleased to provide the following responses to the questions posed.

With regard to the ACS' views on the quality of currently funded coal R&D, the Society is not prepared at this time to comment without the benefit of detailed analysis. However, a significant number of the basic coal research papers published in peer reviewed journals are based on research that received DOE support.

Concerning peer review, the ACS statement is based on the recognition that factors other than peer review influence the funding of DOE projects--for example, geographic distribution may influence the addition of projects during the Congressional budget process. The peer review process is applied at DOE; however, the extramural research community is not involved adequately. The ACS Division of Fuel Chemistry believes that targeted programs from Congress, research at Energy Technology Centers, and research at National Laboratories would benefit from peer review by the extramural research community.

We appreciate this opportunity to express our views.

Sincerely yours,

Thomas G. Squires

Thomas G. Squires
Chairman
ACS Division of Fuel Chemistry

OSPA/atr

Mr. BOUCHER. At this time, I am going to surrender the Chair to the gentleman from Texas, Mr. Chapman, who will Chair the balance of the hearing this morning.

PANEL 3: PETROLEUM R&D

Mr. CHAPMAN [presiding]. Our third panel this morning concerns petroleum, oil and gas, and consists of Dr. William Fisher, the State Geologist of the State of Texas. Dr. Fisher, it is good to see you back in Washington. Dr. Raymond C. Rex, Jr., representing HYCRUDE. Dr. Rex, it's good to have you with us. Dr. Read Holland, Director of the School of Mines and Energy Development at the University of Alabama. We are glad to have you with us today. Mr. Raymond Thomasson, representing Pendleton Land and Exploration. Mr. Thomasson, it's good to have you with us.

We welcome each of you to this hearing. At this time, before we begin the actual testimony of the witnesses, I know that my colleague from Texas, from San Antonio, has some comments that he would like to make in the form of an opening statement. At this time, I would recognize Mr. Lamar Smith.

OPENING STATEMENT OF HON. LAMAR S. SMITH, THE U.S. REPRESENTATIVE IN CONGRESS FROM THE 21ST DISTRICT IN TEXAS

Mr. SMITH of Texas. Thank you, Mr. Chairman. I might add now that we Texan's form a monopoly of the Members who are on this Committee, we ought to make common cause and get a whole lot done for the oil industry.

I do have an opening statement and should we have a journal vote, as we anticipate in about five minutes, I would like to submit some questions for Dr. Fisher if I am not able to return after the journal vote.

Dr. Fisher, I just want to welcome you. It's always good to have someone here from Texas. I appreciate your expertise. I have met you very briefly before, and we are fortunate to have your testimony today.

Mr. Chairman, in the last few days, the price of West Texas crude oil has dropped below $16.00 a barrel. This could be the final blow to the independent oil-producing industry which has already seen a decline by more than half in the number of operating drilling rigs over the last year and a half.

Americans in all parts of the country should be concerned, for this situation has broad implications for the economic future of our country and for our ability to remain a world power. By allowing ourselves to become depending on foreign sources for more than 40 percent of our oil, we have now given OPEC a weapon that is equal to any in our military arsenal.

Last year, U.S. oil production fell 4.5 percent while demand rose 1.8 percent. This continues to slide towards greater dependence on foreign oil, which last year contributed $42 billion to the United States trade deficit.

It is past time to develop a plan that will ensure our ability to produce oil in sufficient quantities to run our economy and control our future. We must find ways to reduce oil imports, make domestic exploration and production profitable, and ensure the availability of future supplies.

We need, in my judgment, to repeal the Windfall Profits tax, restore the oil depletion allowance, develop enhanced oil recovery techniques, and open up public lands for exploration. To do this, we must begin to build a base of understanding and support for the needed changes in policy.

I am pleased to see that the Administration has proposed an increase in funding for enhanced oil recovery research, but I am dismayed that it has proposed a sharp reduction in gas recovery research.

Hopefully, these hearings will shed light on the need to broaden our efforts to revitalize our efforts to revitalize our domestic energy and production and enhance our energy security.

Thank you, Mr. Chairman.

Mr. CHAPMAN. Thank you, Mr. Smith. Again, I would like to take the opportunity to welcome you here. Gentlemen, we do anticipate, I suspect a vote on the journal in just a matter of a few minutes. We will make that round trip as quickly as we can.

Let's begin if we may. I remind you of our five minute rule in the Subcommittee, and ask you please to summarize your comments. We, of course, will submit your full statement for purposes of the record.

I would love the opportunity to get to some exchange of some questions and answers, and perhaps on a more informal basis. Dr. Fisher, you may proceed in your own fashion.

STATEMENT OF DR. WILLIAM L. FISHER, DIRECTOR, BUREAU OF ECONOMIC GEOLOGY AND CHAIRMAN, DEPARTMENT OF GEOLOGICAL SCIENCES, THE UNIVERSITY OF TEXAS AT AUSTIN, AUSTIN, TX

Dr. FISHER. Thank you, Mr. Chairman and Congressman Smith. You and this Committee have been, along with many of us, concerned with the low and declining level of oil and gas Federal funding over the past few years. I am pleased to report that some steps have been taken that begin to arrest this decline, and I think some significant steps have been put into place that will help in the coordination and focusing of an oil and gas research and development effort in this country.

I note that the Congressional Appropriation for petroleum and gas research in the Fossil Energy budget in DOE are at about $40 million, and that's 20 percent better than what we had in the previous fiscal year. I am also pleased to see that the Administration's fiscal year 1989 request for petroleum research and development in the fossil energy budget, while it is still low, is 40 percent greater than what their request was in fiscal year 1988.

Particularly, as Congressman Smith just pointed out, their current oil recovery research request of about $17 million is nearly double of what they asked for last year, and it's about on part with what the Congressional Appropriations have been.

These are really levels that are quite modest numbers, I think, compared with the expenditures that we make in other areas of energy resources, compared with what oil and gas contributes to our primary energy sources, and particularly on what oil and gas production response could be to research. But, they are steps in the right direction, and I think it's important to make that acknowledgement.

There are a few administrative steps that the DOE has taken that I think are in the right direction, or the direction to begin to restore some emphasis in the area of oil and gas research. As you will recall last July, Secretary Wampler indicated that DOE was creating an Office of Geoscience Research. That Office has been established. They are in the process of recruiting a distinguished geoscientist for that position. I think it is to be filled fairly soon.

Another aspect which I think is very important that I am pleased to report to this Committee, is that last week Assistant Secretary Wampler signed a letter of intent, which is attached to my testimony, indicating that the Department intends to enter into a formal arrangement and to support the recently established Geoscience Institute for Oil and Gas Recovery Research. The initial work of that Institute will be to develop and present to the Department, a comprehensive geoscience and enhanced oil and gas recovery program, as provided for in the fiscal year 1988 continuing resolution. That Geoscience Institute has been established at the University of Texas at Austin, and will be administered by the University on behalf of 11 other participating universities or state entities throughout the Nation situated in the oil and gas producing areas of the country. It represents a major portion of the Nation's public sector expertise in this area. I think the important part of putting together a consortium of this sort is simply to get to the kind of coordination, the kind of targeting, the kind of central thrust that the Energy Research Advisory Board and others have indicated in the past as being very, very important.

I think this mechanism as it is in place, along with the Office of Geoscience Research within DOE, is the kind of mechanism that will give us the approach and the structure toward a very effective R&D effort in oil and gas and the kind of response that we can likely expect from it.

We estimate and what we would urge the Congress to consider, is an additional $20 million in appropriations. We think that can be used effectively and efficiently, that is, above and beyond the current level of appropriations in the area of geosciences research.

Getting the monies through either current or through future appropriations that would be made available to the institute will be matched on a 50/50 basis, primarily with the resourcing from private sector or from State contributions. The criticality of that is to have a high degree of relevance to that work, simply by demonstrating that the research is a product of the support from both the Federal, private and State sectors.

Mr. Chairman, everyone comes to this Committee asking for funds. Let me simply in conclusion, make one brief example of what the kind of payoff in near term in oil and gas research I think can be.

Almost four years ago, the University of Texas Board of Regents funded a research project at UT for $2 million over that four-year period of time, primarily to develop geologic models of the University's land reservoirs in West Texas. That work to date has identified some 65 million barrels of additional oil in these old existing reservoirs in West Texas.

If we make the assumption that one-third of this will eventually be produced—and a substantial amount of it is already under production—at an average value of about $20.00 per barrel, the University as a royalty owner in this will receive a return on its investment of 27 to 1, which is a pretty good investment.

I think if we were to extrapolate in the kind of proposal that we are talking about here, if we were to extrapolate that particular experience nationally—let's make the assumption that on a national basis we would be only half as successful as we were in the University of Texas effort—and we were expending say $20 million per year, that should result in the localization by this extrapolation of about 160 million barrels of oil.

If you were to make the further assumption that we only recover about one-third of it which is what we did in the case of the UT assumption, and if we make the assumption on what the value of that oil would be in a public sense—not in terms of what it is to the operator—those estimates on a net national benefit value of a domestic produced barrel of oil would run all the way from $2.00 to over $100.00.

If you take the $100.00 figure that the Harvard people use in trying to establish what is the value, the economic premium and the national security premium, if you just take that value you wind up with a public return—if we just simply be half as successful as we were in the effort in West Texas—public return on that investment of about 30 to 1, which is a substantial near term type of payback to a targeted concentrated oil and gas research effort.

I think the structure is in place, I think the resource is ample, I think its conversion to producible reserves is amenable to the kind of efficiencies that can be provided by targeted research and development.

Further, the national need for stable, not declining, production is great in terms of the economy, the balance of trade, and national security.

I urge this Congress and this Committee to give serious consideration to a substantially enlarged oil and gas recovery research program. The payback both in the near term and the longer term, I think, to the Nation would be immense.

Thank you, Mr. Chairman.

[The prepared statement of Dr. Fisher follows:]

Statement of

William L. Fisher

The University of Texas at Austin

before

Committee on Science, Space, and Technology

Subcommittee on Energy Research and Development

U.S. House of Representatives

March 3, 1988

Mr. Chairman and Members:

I am William L. Fisher, Director of the Bureau of Economic Geology and Chairman of the Department of Geological Sciences at The University of Texas at Austin.

I.

Over the past several years the federal expenditure for oil and gas related research has declined steadily and substantially to only about a percentage point of the Department of Energy's non-defense research and development budget. This is in spite of the fact that oil and gas provide 65 percent of the U.S. primary energy requirements and will continue to be the dominant sources well into the next century. It is also in spite of the fact that the U.S. has lost 6.5 percent of its oil production capacity, more than 11 percent in the Lower 48, in the past two years after a half-decade of stable production.

However, I am pleased that some steps to arrest the unfortunate decline in oil and gas research funding have been taken, and significant steps have been put into place to coordinate and focus the oil and gas research and development effort.

I note that Congressional appropriations for petroleum research in the Fossil Energy budget for this fiscal year are at $40 million, nearly 20 percent more than the FY87 appropriations.

I am also pleased to see that the Administration's FY89 request for petroleum research and development in the Fossil Energy budget is 40 percent greater than their FY88 request. Notably, the current oil recovery research request of about $17 million is nearly double the FY88 request and on par with FY88 Congressional appropriations. These oil and gas research levels are really quite modest numbers compared with expenditures for other energy research items and the role of oil and gas in U.S. energy supply. But they are steps that are directionally right.

I commend the Department of Energy for other actions taken over the past few months, steps also in the right direction.

Assistant Secretary Wampler before this Committee last July indicated the Secretary was creating an Office of Geoscience Research. This central office for geoscience research, as recommended by the Department's Energy Research Advisory Board (ERAB) is critical to the research and development coordination also recommended by ERAB. I understand the Department is now recruiting for a distinguished geoscientist to direct that office and that the position will soon be filled.

Also last July Assistant Secretary Wampler announced the formation of a coordinating task force within the Department relative to its hydrocarbon research program. This should provide at least a means of coordination of Department programs.

Finally, I am most pleased to report that this past week Assistant Secretary Wampler signed a letter of intent (copy attached) indicating that the Department intends to enter into *a formal arrangement* with and to support the recently established Geoscience Institute for Oil and Gas Recovery Research. The initial work of the Institute will be to develop and present to the Department a comprehensive geoscience and enhanced oil and gas recovery program, as provided for in the FY88 Continuing Resolution.

The Geoscience Institute has been established at The University of Texas at Austin and is administered on behalf of the University and 11 other participating universities or state entities by the University's Bureau of Economic Geology. The 12 universities and state entities form a national consortium situated throughout the oil and gas producing areas of the Nation. The Consortium represents a major portion of the Nation's public sector expertise, interest, and current programs in oil and gas recovery research. It is composed of geoscience units--state geological surveys, academic departments, and energy centers--with significant expertise in petroleum engineering, geophysics, and geology and with active programs in oil and gas recovery research. While the consortium consists of 12 universities or state entities at present, other entities are free to and will be encouraged to participate. An external group, mostly from the private sector, will constitute an advisory committee to the Institute. All funds received will be matched by non-DOE sources, chiefly private and state, thereby assuring the critical federal, state, and private sector mix, and higher relevance of the research.

As members of this Committee will recall, the Department's Energy Research Advisory Board (ERAB) one year ago urged the creation of six regional centers of excellence, one in each major U.S. petroleum province, to conduct and coordinate interdisciplinary, problem-oriented oil and gas research and development. The presently constructed Institute for Oil and Gas Recovery Research, as a national consortium that DOE intends to support, is a structural and organizational alternative to ERAB's original concept of six centers. I am pleased to report that both Mr. John H. Schoettler, Chairman of ERAB, and Dr. Robert J. Weimer, Chair of ERAB's Solid Earth Science Panel, support the current Institute structure with enthusiasm.

The appropriate structure--the DOE Office of Geoscience Research and the Geoscience Institute--is in place to provide coordinated, targeted research of both near-term and longer-term payout. While the Institute Consortium plans to report to the Department a comprehensive plan for geoscience oil and gas recovery research before the end of FY88, we believe it is critical that the Congress provide substantial increase in geoscience research in the FY89 budget. We estimate that an additional $20 million in appropriations can be utilized effectively and efficiently. Any of these monies made available to the Geoscience Institute for Oil and Gas Recovery Research would be matched at least on a 50/50 basis, resulting in a national annual effect of $40 million. An effort at that level will have significant impact.

II.

Mr. Chairman, substantial analyses of the U.S. oil and gas resource base have been done in recent years. Although the conventional wisdom has been that the ability of the U.S. oil and gas resource base to yield producible reserves is limited and declining, more recent analyses show quite to the contrary. The domestic resource is huge--some 335 billion barrels of oil will be left behind in known reservoirs with present level of deployed development. Our analysis indicates that about 95 billion barrels of that volume remain as conventionally movable oil.

Through detailed and sophisticated geologic modeling a significant part of the movable oil can be contacted by strategic, targeted infill drilling and produced. A portion of the remaining residual oil--240 billion barrels--can also be converted to producible reserves with both advanced geologic modeling and advanced extraction technology. These requirements can be met with the level and kind of oil and gas recovery research and development program I am recommending here.

If one-half the remaining mobile oil and one-quarter the remaining residual oil can be produced over the next 40 years, the resulting volume would be nearly 110 billion barrels. That volume plus current proved reserves is sufficient to keep U.S. production (3.0 billion barrels annually) stable for the next 45 years. The implication of such results for the U.S. economy and national security is profound.

III.

In conclusion, let me speak briefly to the expected payback of a public research investment in oil and gas recovery research. At The University of Texas the Board of Regents nearly four years ago established a research program to characterize and geologically model oil reservoirs on lands held by the University in West Texas. The research was targeted directly to identifying additional producible oil. To date, with a research expenditure of $2 million some 65 million additional barrels of oil have been localized in old, existing reservoirs by the project. Some of the volumes have already been produced and some are now under development. Assuming that one-third of the localized volumes is ultimately produced, at an average value of $20 per barrel, a conservative assumption, the University as royalty owner will receive a return on its investment of 27 to 1.

If we extrapolate the University Lands results nationally, but assume a success only half that achieved in the University Lands program, a $20 million research investment would result in a localization of some 160 million barrels of oil. The net national benefit of a barrel of oil produced domestically has been calculated in the literature at a range of $2 to more than $100 per barrel. However, a conservative calculation by Professor Bill Hogan and his associates at The Energy and Environmental Policy Center at Harvard placed the value at $11 per barrel. If one-third of the 160 million volumes resulting from the $20 million research investment is ultimately produced, the public return on the investment would be nearly 30 to 1.

IV.

The research structure is in place, the resource is ample, and its conversion to producible reserves is amenable to the kinds of efficiencies that can be provided by targeted and coordinated research and development. Further, the national need for stable, not declining, production is great in terms of the economy, the balance of trade, and national security. I urge the Congress and this Committee to give serious consideration to a substantially enlarged oil and gas recovery research program. The payback to the Nation would be immense.

Department of Energy
Washington, DC 20585

SUBJECT: Statement of Intent

- Public Law 100-202, H.J. Res. 395, known as the FY 88 Continuing Resolution provides funding for the Department of Energy. As part of the conference managers' report leading up to enactment of this legislation, there are provisions that allow for $500,000 to be used for oil and gas program development support by outside experts, as needed, to assist DOE, and thus Fossil Energy, in developing comprehensive geoscience and enhanced oil recovery R&D programs. Congress envisioned that in the resulting program: (1) the effort would be done by a variety of organizations through a competitive process; (2) if consortia were established by non-Government groups to provide proposals, then any additional administrative costs by the consortia should not be borne by the government; (3) research be funded on a project-by-project basis with high cost-sharing encouraged.

- The Geoscience Institute for Oil and Gas Recovery Research, as established by the University of Texas at Austin, represents a major portion of the nation's public sector expertise and interest in oil and gas recovery research. The Department intends to support such a consortium, which is comprised of state geological surveys and university departments nationally with significant expertise in petroleum engineering, geophysics, and geology, and active programs in oil and gas recovery research.

- The Department intends to enter into a formal arrangement with the Geoscience Institute, as established, provided that there is developed the appropriate and acceptable documentation on the part of both parties in a reasonable and acceptable time period. These include, but are not limited to: Submission of an unsolicited proposal (USP) to the Department; acceptance of USP; and award of appropriate contractual instrument.

It is recognized that not all of the details have been finalized and agreed to by all parties. Fossil Energy is and remains committed to work with the Geoscience Institute to see this activity to fruition.

J. Allen Wampler
Assistant Secretary
Fossil Energy

Mr. CHAPMAN. Thank you, Dr. Fisher. I understand you defined that substantially enlarged budget would be a $20 million figure.

Dr. FISHER. It would be $20 million in addition to the current levels, yes, sir.

Mr. CHAPMAN. Gentlemen, we have had a call to the floor for a vote. That round trip will take about 15 minutes. With your indulgence, let us adjourn the hearing for a period of 15 minutes and we will be back just as quickly as we can be. Thank you.

[This hearing recessed at 11:07 a.m. for a vote, to be reconvened at 11:25 a.m. this same day.]

Mr. CHAPMAN. The Subcommittee will come to order. Gentlemen, I appreciate your indulgence of the House floor activity. We are ready to proceed. Dr. Rex, you may proceed in your own fashion.

STATEMENT OF DR. RAYMOND C. REX, JR., MANAGER OF RESEARCH AND ENGINEERING, HYCRUDE CORP., CHICAGO, IL

Dr. REX. Thank you, Mr. Chairman. My name is Raymond Rex, and I am Manager of Research and Engineering for HYCRUDE Corporation.

Eastern oil shale is an important domestic energy resource that could supply over 400 billion barrels of oil, if properly developed, and play a major role in reducing our nation's dependence upon imported oil. As we are well aware, the United States continues to import a significant and increasing portion of the liquid fuels necessary to keep our society functioning and to supply our defense needs.

Over the past few years, the oil shale research program has received only minimal support from the Administration even though oil shale has the potential to be a major contributor to our domestic supply of transportation fuel. In recognition of the strategic importance of Eastern Oil Shale, Congress has shown excellent judgment and foresight in maintaining a modest funding level for this valuable research and development program since fiscal year 1985.

These research programs have addressed a wide range of issues and have produced encouraging results. It has been shown that processing methods specifically developed for Eastern oil shales result in oil yields that are commensurate with those obtained for Western oil shales of similar carbon content.

It has also been shown that lower-grade shales can be enriched by beneficiation. Beneficiation techniques under development in this program can reduce up to 70 percent of the amount of material to be processed in the retorts, thus helping to reduce processing plant costs. Additionally, beneficiated oil shale exhibit up to 40 percent lower hydrogen consumption, which can reduce operating costs.

HYCRUDE Corporation is now in the final year of a successful research program for the development of the movingbed hydroretorting process for Eastern oil shales. In the third year of the program, tests will be conducted in 60-tons-per-hour, six-foot diameter cold-flow model to determine the maximum concentration of fines that can be fed with the coarse shale without adversely affecting gas distribution and then the oil yield. These fines will increase resource utilization.

Additionally, the final stages of this program will address the combination of oil shale fines gasification and hydroretorting and the potential of synthesis gas retorting of oil shales to further reduce hydrogen requirements.

Upon completion of this three-year DOE research contract at the end of fiscal year 1988, the development of this process will have reached a stage where the next logical step is the construction of a small demonstration plant.

The existing database is a valuable tool for other researchers in the development of second generation Eastern oil shale retorting technologies. The development of these new processes will further improve the technology and the process economics for recovering oil from Eastern oil shales.

It is imperative to continue to strive for these improvements to hasten a day when it is feasible for the U.S. to become independent from imported oil and to ensure that the best technologies are available should a sudden change of events abruptly dictate the production of alternative fuels.

In fiscal year 1988, a unique three-year program in oil shale research has been initiated. This program, which utilizes Eastern shale processing and environment database acquired over the past several years, takes an innovative, cost-effective team approach to developing a second generation retorting technology.

In addition to the development of the new retorting processes, the scope of work encompasses raw shale treatment and enrichment, mitigation of environmental impacts and product upgrading.

The Institute of Gas Technology in Chicago is the prime contractor responsible for the development of pressurized fluidized-bed hydroretorting process. IGT also coordinates research teams under subcontract for the development of peripheral technologies such as beneficiation and environmental mitigation that are vital parts of an integrated oil shale retorting plant.

There is a free exchange of information among the researchers and meetings are held to ensure that each research subcontractor is cognizant of developments that could potentially impact his area of research. This direct communication provides the expeditious exchange of information between experts with diverse backgrounds so that process development is accelerated.

The subcontractors on the project team include the Mineral Resource Institute of the University of Alabama, which in conjunction with the University of Pittsburgh will be responsible for the development of more efficient and economical means to beneficiate the Eastern oil shales. Ohio State University and the Illinois Institute of Technology will participate in the program by developing techniques for removing sulfur and nitrogen from the shale, and removing fines from the shale oil. Tennessee Technological University and the University of Michigan are evaluating the environmental impacts and the feasibility of recovering potentially leachable metals.

HYCRUDE Corporation supports a $6 million program for Eastern oil shale in fiscal year 1989, consisting of the following: $2.5 million to continue the DOE contract for the development of the PFH process under Basic Process Research; $2 million for novel concepts research. The funding is necessary to extend the existing efforts under novel concepts awards and to stimulate further research; $1.5 million for environmental studies which are essential developing technologies.

Thank you for the opportunity to present my views to you today and for the past support your Committee has given to the Eastern Oil Shale Program.

I will be happy to answer any questions you may have concerning Eastern Oil Shale program.

[The prepared statement of Dr. Rex follows:]

OIL SHALE TESTIMONY

STATEMENT BY RAYMOND C. REX, JR.
MANAGER OF RESEARCH AND ENGINEERING, HYCRUDE CORPORATION
HOUSE COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
March 3, 1988

Madame Chairman and Members of the Subcommittee:

My name is Raymond Rex. I am Manager of Research and Engineering of HYCRUDE Corporation. This testimony addresses the Department of Energy's non-nuclear R&D Authorization for oil shale research in fiscal year 1989.

Eastern oil shale is an important domestic energy resource that could supply over 400 billion barrels of oil, if properly developed, and play a major role in reducing our Nation's dependence upon imported oil.The United States continues to import a significant and increasing portion of the liquid fuels necessary to keep our society functioning and to supply our defense needs.

Over the past few years the oil shale research program has received only minimal support from the Administration even though oil shale has the potential to be a major contributor to our domestic supply of transportation fuel. In recognition of the strategic importance of Eastern Oil Shale, Congress has shown excellent judgement and foresight in maintaining a modest funding level for this valuable research and development program since FY'85.

These research programs have addressed a wide range of issues and have produced encouraging results. It has been shown that processing methods specifically developed for Eastern oil shales result in oil yields that are commensurate with those obtained for Western oil shales of similar carbon content. It has also been shown that lower grade shales can be enriched by beneficiation. Beneficiation techniques under development in this program, can reduce up to 70% of the amount of material to be processed in the retort, thus helping to reduce processing plant costs and, beneficiated oil shale requires up to 40% lower hydrogen consumption, which can reduce operating costs.

In this third year of the program tests will be conducted in a 60 ton per hour, 6 foot diameter cold flow model to determine the maximum concentration of fines that can be fed with the coarse shale without adversely affecting gas distribution and thus the oil yield.

Upon completion of this three year DOE research contract, the development of this process will have reached the stage when the data base is in place and the next logical step is the construction of a small demonstration plant. The final stages of the initial program will study the combination of oil shale fines gasification and a hydroretorting. Synthesis gas retorting of oil shales (to further reduce hydrogen requirements) will also be investigated.

HYCRUDE Corporation is now in the final year of a successful research program for the development of the moving-bed hydroretorting (HyTort) process for Eastern oil shales.

The moving-bed hydroretorting data base is a valuable tool for other researchers in the development of second generation Eastern oil shale retorting technologies. The development of these new processes will further improve the technology and the process economics for recovering oil from Eastern shales. It is to continue to strive for these improvements to ensure that the best technologies are available should a sudden change of events abruptly dictate the production of alternative fuels.

In early fiscal year 1988, a unique three-year Eastern Oil Shale research program was initiated. This program, which utilizes the Eastern shale processing and environmental data base acquired over the last several years, takes an innovative, cost-effective team approach to developing a second generation retorting technology. In addition to the development of the new retorting process, the scope of work encompasses raw shale treatment and enrichment, mitigation of environmental impacts and product upgrading.

The Institute of Gas Technology in Chicago is the prime contractor responsible for the development of the pressurized fluidized-bed hydroretorting (PFH) process. IGT also coordinates research teams under subcontract for the development of peripheral technologies such as beneficiation and environmental mitigation that are vital parts of an integrated oil shale retorting plant. There is free exchange of information among the researchers and meetings are held to ensure that each research subcontractor is cognizant of developments that could potentially impact his area of research. This direct communication provides the expeditious exchange of information between experts with diverse backgrounds so that process development is accelerated.

The subcontractors on the project team include the Mineral Resources Institute of the University of Alabama, which, in conjunction with the University of Pittsburgh will be responsible for the development of more efficient and economical means to beneficiate Eastern oil shales. Ohio State University and the Illinois Institute of Technology will participate in the program by developing techniques for removing sulfur and nitrogen from the shale, and removing fines from the shale oil. Tennessee Technological University and the University of Michigan

are evaluating the potential environmental impacts and the feasibility of recovering potentially leachable metals.
HYCRUDE Corporation supports a $6.0 million program for Eastern Oil Shale R&D in FY 1989 consisting of:

o $2.5 million in to continue the DOE contract for the development of the PFH process under Basic Process Research.

o $2.0 million be for Novel Concepts Research. This funding is necessary to extend efforts under existing novel concepts awards and to stimulate further research through the issuance of a new Novel Concepts PRDA.

o $1.5 million for Environmental Studies which are essential to developing technologies.

Thank you for this opportunity to present my views to you today and for the past support your committee has given to the Eastern Oil Shale Program. I will be happy to answer any questions you may have concerning the Eastern Oil Shale Program.

Basic Process Research

Retorting Eastern oil shale in the presence of hydrogen has been shown to dramatically increase the yield of oil obtained when compared to conventional thermal retorting. A novel approach is now being taken to develop a second generation retorting concept that will maximize the benefit obtainable by retorting Eastern oil shales in the presence of hydrogen. The development of this new retorting process concept is comprehensive: it not only includes the development of a new retorting technology itself, but the development of the peripheral technologies such as shale pretreatment, gas cleanup, oil upgrading, and mitigation of potential environmental impacts, that can have a great effect on the overall process economics and efficiency of shale retorting. The concurrent development of the individual building blocks that make up an oil shale retorting process plant will result in greater compatibility and optimization of the various processes than would result if each were developed independently.

Because no one organization has expertise in all of these research areas, a multi-disciplinary research team is developing the new process concept, which revolves around the pressurized, fluidized-bed hydroretorting (PFH) process conceptualized by the Institute of Gas Technology (IGT). The PFH process provides a more efficient method of contacting the hydrogen rich gases with the oil shale. Previous work in hydrogen was performed using larger size pieces of oil shale which were fed by gravity through a moving-bed and were contacted countercurrently with hydrogen rich gas. In PFH, smaller size shale particles are fluidized with hydrogen rich gas which improves the thermal efficiency of the process and results in faster conversion of the shale to oil.

Furthermore, the PFH process can more readily be used to process oil shale that has been beneficiated to enrich the organic content of the feed. Beneficiation of eastern oil shales has been shown to result in a greatly enriched feedstock, which reduces the required capacity of the retorting plant per unit of oil produced. However, beneficiation requires that the shale be finely ground for processing. In order for beneficiated shale to be processed in the moving-bed hydroretorting process, the beneficiated shale must first be briquetted so that it can be fed into the retort at a larger particle size which can be handled in this type of retort.

The University of Alabama's Mineral Resources Institute (MRI) is leading the research effort to economize the beneficiation process and to provide feedstock suitable for retorting in the PFH process. MRI is being assisted in these activities by the University of Pittsburgh.

Other members of the research team are the Illinois Institute of Technology, Ohio State University, Tennessee Technological University and the University of MIchigan. These researchers will participate in the program by developing techniques for removing sulfur and nitrogen from the shale, removing fines from shale oil, and evaluating the potential environmental impacts and the possibility of recovering potentially leachable metals. The research team concept ensures that substantial improvements in the overall process scheme and economics are attained as quickly as possible.

Hycrude Corporation recommends $2.5 million for the continuation of the development of the PFH process concept by a multidisciplinary research team.

Novel Concepts Research

At the end of FY'86, three awards were made for research on novel concepts for oil shale processing. One of the projects was for research on an inert-gas, atmospheric-pressure fluidized-bed retort system for eastern oil shale, which is being developed by the Kentucky Center for Energy Research Laboratory. The continued support and expansion of research on novel concept is important to ensure that state-of-the-art retorting techniques will be available for the development of the Eastern oil shale resource. An additional novel concepts solicitation, which does not require co-funding by research teams, should be published in FY'89.

Hycrude Corporation recommends $2.0 million in FY'89 for continuing novel concepts research.

Environmental Studies

As long as research is conducted to develop new Eastern oil shale retorting methods and new technologies for shale treatment, product upgrading, and other peripheral technologies, environmental research should be conducted to determine the potential environmental impacts of these new processing concepts so that the technological aspects of minimizing environmental concerns can be addressed.

Water management(both within the retorting process plant, and in the nearby geographic area), air quality, and spent shale disposal issues should be investigated, and research should be performed to mitigate any environmental impacts discovered as a result of the newly identified processing concepts.

Hycrude Corporation recommends $1.5 million in FY'89 to conduct environmental studies.

Mr. **Chapman**. Thank you very much, Dr. Rex. Dr. Holland, you may proceed.

STATEMENT OF DR. J. READ HOLLAND, DIRECTOR, THE SCHOOL OF MINES AND ENERGY DEVELOPMENT, THE UNIVERSITY OF ALABAMA, TUSCALOOSA, AL

Dr. **Holland**. Thank you, Mr. Chairman. My name is Read Holland. I am the Director of the School of Mines and Energy Development at the University of Alabama. The School of Mines and Energy Development conducts and supports mineral and energy related research which responds to state and national needs.

In carrying out this research, the University over the years, has committed substantial funds and effort to the research aimed at the development of Alabama Resources and improving the Nation's energy posture. The scope our efforts are quite broad. It includes clean coal, coal sciences, oil shale, tar sands, foundry and mining waste, alternative diesel fuels and energy storage.

I would like to speak today to the area of oil shale, which is one of our areas of focus. We are looking at processes designed to economically recover liquid hydrocarbons from oil shale. Dr. Rex has spoken to you of the vast quantity of oil available in the Devonian shales in the Eastern and Central parts of the United States.

In Alabama, we have about 4 billion barrels of oil potentially recoverable from that resource, and we are working very diligently to improve our prospects of being able to recover that oil.

Until recently, Eastern shales have been fairly well ignored. The perception has been that the Eastern shales are substantially poorer in grade than the Western shales. In conventional assay techniques, Eastern shales assay 10 to 13 gallons per ton of shale where Western shales assay 30 to 35 gallons per ton. These two shales have essentially the same carbon content, the difference being that the Eastern shale is hydrogen deficient. You simply, in conventional retorting, don't convert the carbonaceous material to liquid hydrocarbons.

About 10 years ago, the Mineral Resources Institute of the School of Mines and Energy Development undertook a process to look at innovative and advanced techniques for improving the process and characteristics of the Alabama oil shale. One of the techniques that we looked at was the beneficiation technique that we used to upgrade the shale, a flotation technique. Our early results indicated that we could recover 20 to 25 gallons per ton, which was very encouraging news.

We continued to work on that process. Now the yields are very much higher, in the range of 35 to 40 gallons per ton of treated shale. The way that you do this is, you grind the shale very fine and release a kerogen fraction or the mineral constituent known as kerogen, and float that off in a froth and recover that kerogen.

You can reject, as Dr. Rex said, 70 to 85 percent of the shales barron. That has tremendous impact on plant cost and other economics of the process.

In unrelated and independent work that was begun over 10 years ago, the HYCRUDE Corporation, a division of the Institute of Gas Technology, developed their HYTORT process which is a hydrogen retorting process primarily for Eastern oil shales. The demonstrated an increase in yields of approximately two or more over conventional techniques.

After hearing this and after some time passed, we approached the IGT and the Department of Energy for a joint program looking at the combination of these two techniques that gave promising factors for increasing the yield from Eastern shales.

In 1985 we started a joint project with HYCRUDE, looking at the technical, environmental and economic feasibility of a combined beneficiation and hydroretort processing for extracting maximum oil yields at minimum cost. At this point in time, we are able to upgrade the oil yield to approximately 90 gallons per ton of shale processed. This is a factor of six to seven over what you would get by conventional processing techniques that were developed by Western shales.

We are now in the third year of this project. We expect to present to DOE the design features and capital and operating costs of commercial plant operating on the scale of 20 to 50,000 barrels of oil per day for processing Eastern shale.

We are seeing a marked improvement in the economics that were earlier projections from Western shale processing, and think that at this point it is going to come in somewhere in the $30.00 per barrel cost.

We feel that the continuation of the Eastern Oil Shale Project is a very important aspect of our total energy posture, particularly in the fossil energy area, and would recommend to you a continuation of the program at the level of $6 million for the Pacific Eastern Oil Shale Research.

This includes $2.5 million for a second generation retorting technology that IGT is working on; and improvements in the beneficiation technique to enhance the attractiveness of their pressurized fluidized bed hydroretorting process. We think it is important that this program proceed and think that it has promising benefits that we are beginning to show.

Thank you for the opportunity to share these views with you.

[The prepared statement of Dr. Holland follows:]

Statement by Dr. J. Read Holland, Director

The School of Mines and Energy Development

The University of Alabama

Before the House Subcommittee on Energy

Research and Development Hearings

on The Department of Energy's Authorization

for Fiscal Year 1989

March 3, 1988

This testimony pertains to fiscal year 1989 Department of Energy R&D funding for oil shale research. The University of Alabama strongly endorses the continuation of specific research on Eastern oil shale at a funding level of $6 million in fiscal year 1989 in support of the development of a second generation of technology that promises to enhance the attractiveness of the Eastern shales as a potential major energy resource of the future.

Madam Chairman and Members of the Subcommittee:

My name is J. Read Holland. I am Director of the School of Mines and Energy Development (SOMED) at The University of Alabama. The School of Mines and Energy Development conducts and supports mineral and energy related research which responds to state, regional, and national needs. In carrying out this mission, The University over the years has committed substantial funds and human resources to research aimed at development of processes for improving the nation's energy position. One area of activity has focused on the investigation of processes designed to economically recover oil products from U.S. oil shales.

The Devonian age oil shales of the Central and Eastern United States represent a large, attractive undeveloped fossil energy resource. The "known resources" of the Devonian shales, in place, are estimated to contain at least 400 billion barrels of oil that would be recovered by the application of novel extraction technology now under development.

Until recent years, the Eastern shales were largely ignored as a source of liquid fuel production because of the low oil yields when processed by the thermal retorting procedure (direct heating) developed specifically for the Western Green River formation oil shales. Typically, the "pyrolysis" approach yields 10 to 13 gallons of oil per ton from the Eastern shales as compared to 25 to 35 gallons from the Western shales. This is attributed to a deficiency of hydrogen required to convert the carbonaceous material (kerogen) to crude oil.

In 1978, The Mineral Resources Institute (MRI), a division of The School of Mines and Energy Development, undertook research to develop innovative and advanced technology specifically tailored to improving the processing characteristics of Alabama oil shale. One of the techniques that showed promise was a beneficiation process, developed at MRI, for upgrading the raw shales to recover products yielding 30 to 35 gallons of oil per ton by pyrolysis treatment of raw shales that yielded only 10 to 13 gallons per ton. The beneficiation process consists of grinding the shales to a fine size to free the carbonaceous oil yielding fraction "kerogen" from relatively barren shale followed by froth 'flotation' to recover a kerogen-enriched product. In the process, 65 to 75 percent by weight of the raw shale is rejected as an essentially kerogen-free waste that need not be processed further to recover the oil. The early work was largely exploratory and focused on application of the process to an Alabama oil shale. To date we are continuing to improve the process from a technical and economic standpoint and the continued research is expected to lead to further refinements.

In unrelated investigations begun during the 1970's, HYCRUDE Corporation, a subsidiary of Chicago-based Institute of Gas Technology (IGT) developed the HYTORT process for increasing the oil extractions from Eastern oil shales by a factor of two or more. The process (hydroretorting) involves heating the shale at elevated temperature and pressure in a hydrogen-rich atmosphere to convert the hydrogen-deficient carbonaceous kerogen to oil. By combining the MRI beneficiation process and HYTORT processes, oil shales yielding 13 gallons of oil per ton by simple pyrolysis can be upgraded by beneficiation to products that yield up to nearly 90 gallons of oil per ton when treated by the HYTORT process.

With funds made available by this subcommittee and the Congress, the Department of Energy, in fiscal year 1985, contracted with MRI and HYCRUDE for a joint research project to investigate and evaluate the technical, environmental, and economic feasibility of combined beneficiation-hydroretort processing for extracting maximum oil at minimum cost from U.S. oil shales. We are now in the third and final year of the grant. At the completion of the research we expect to have in place for presentation to DOE the design features, and the capital and operating costs of a conceptual commercial plant producing 20,000 and 50,000 bbls/day of oil product from Eastern oil shale by beneficiation and moving-bed hydroretort processing.

The pressurized fluidized-bed hydroretorting (PFH) process R&D program that I recommend to the Subcommittee for FY '89 funding is a continuation of a three year program undertaken by the Institute of Gas Technology, in fiscal year

1988 with funds provided by DOE. This process offers an exciting opportunity to develop a second generation hydroretorting technology for Eastern oil shale that we strongly believe will show an advantage over moving-bed hydroretorting from the operating and cost effectiveness standpoints. Processing of upgraded products recovered by the MRI beneficiation process is expected to further enhance the attractiveness of the PFH approach. The School of Mines and Energy Development at The University of Alabama recommends a funding level of $6 million in fiscal year 1989 to continue Eastern oil shale research which includes $2.5 million for the PFH process.

Thank you for the opportunity to share my views with you today. I will be pleased to address any questions you may have and should you require any additional information at a later date, we will be pleased to provide it.

Mr. **Chapman**. Thank you, Dr. Holland. Dr. Thomasson, if you would like to proceed.

STATEMENT OF DR. M. RAY THOMASSON, EXECUTIVE VICE PRESIDENT OF EXPLORATION AND PRODUCTION, PENDELTON LAND AND EXPLORATION, INC., ENGLEWOOD, CO

Dr. **Thomasson**. Thank you, Mr. Chairman. I am a geologist and geophysicist, and our business is finding oil and gas. In some of my past incarnations, I was with Shell Oil Company for 17 years and one of those hats was in charge of the geologic research for Shell.

The sort of thing that Bill Fisher has described this morning is of keen interest to us. If I could tell you a story about Kansas, which is one of the places that we look for oil. We have plays going on today in North Dakota, Illinois, Ohio, California, Oklahoma and Kansas. In Kansas, there is an old area that has produced 3 billion barrels of oil. It's called the Central Kansas Uplift.

It is an intriguing area, because most of the drilling was done in the 1930's and 1940's—a long time ago. Major companies got out of there probably 40 years ago. In the downturn in the oil business, I looked around to see where we would really be able to do something about and have impact on that 100 billion barrels of oil that is moveable, that Dr. Fisher mentioned, but at this point is unrecoverable.

It looks like Kansas is one of those older, mature places and it looked like a place where maybe you could do that. We went to an area called the Central Kansas Uplift, found that that 3 billion barrels of oil was very poorly understood. It needed a lot of research and we have been doing a lot of that research.

We drilled 37 wells last year, which doesn't sound like very many for Shell. Shell drilled 1,100 wells last year. But 37 wells is a lot of wells for a small company like our own. We are one of some 20,000 very small companies that are out there drilling 85 percent of the wells.

In trying to beat up that area technically, we have brought in very high technology doing the type of seismic that will impress any major company. We were in Mobil's Research Laboratory two days ago showing them some of the things that we are doing. The point is, there is a lot left to be found and produced in some of these old areas.

In that instance, we think there is 20 percent more to be found; 20 percent times 3 billion is 600 million barrels. That's a worthwhile target.

I was shocked when I went back to my old colleagues in Shell and showed them a play in Kansas. They were quite interested. They went to their files and found that they didn't have any maps on Kansas. Not one. Not one geologic map, not one piece of data in all the State of Kansas. Kansas is a pretty big producer. I took the same play to Amoco and they had one map. They had a 1952 land map.

The point being, that major companies are not going to be the companies that produce that additional 600 million barrels. That is a lot of oil. It's going to be guys like me. It is going to be small independents that go out and do it either intelligently or stupidly.

Now we can do it intelligently if we get good research. And we won't go ahead and be able to afford all the kind of research that we need.

I would appeal to you to spend some money on oil and gas research, particularly in enhanced oil recovery research because there is such an opportunity there. As we do that kind of work, we are going to exploring as wel' We are going to be integrating various technologies.

I think the bottom line for us will be beign able to turn that 100 billion barrels of moveable oil into proven reserves. We can do that a lot faster if we get research done today that can be used today to accomplish that objective.

Thank you, Mr. Chairman.

[The prepared statement of Dr. Thomasson follows:]

Science, Space and Technology Committee

Energy, Research and Development Subcommittee

Testimony of Dr. M. Ray Thomasson

My name is M. Ray Thomasson. My education consists of undergraduate and Masters degrees from the University of Missouri - Columbia, both in geology and a Ph.D. in geology from the University of Wisconsin in Madison. Professionally I spent the first seventeen years of my career with Shell Oil Company. Positions during that time included Manager of Geologic Research for Shell Development Company, Manager of Texas, Louisiana and Atlantic Offshore Division, Manager (for Shell Oil Company in the United States) of Forecasting, Planning and Economics and Manager of Strategic Planning for Shell International Petroleum Corporation, London, England. My last position with Shell was as Chief Geologist for Shell Oil U.S.A. Since 1977 I have been working with smaller, independent oil companies. These include McCormack Oil and Gas Company, where I was Vice-President of Exploration; Spectrum Oil and Gas Company where I was President and CEO; and Pend-Oreille Oil and Gas Company where I was President and CEO. My current position is Executive Vice President of Exploration and Production with Pendleton Land and Exploration, Inc.

I maintain my technical interest as a professional even though I am very deeply involved in the business side of the oil business. For instance, I am currently a Distinguished Lecturer for the American Association of Petroleum Geologists on a highly technical subject "Seismic Prediction of Porosity and Hydrocarbon Traps in Carbonate Rocks". In addition I have recently taught courses for the American Association of Petroleum Geologists in their continuing education program.

I represent the smaller independent companies which drill 85% of the exploratory wells in the country and which conduct a significant percentage of the infield development work and enhanced oil recovery work in the United States.

As a practical oil finder I can testify that there is a great deal for us to learn in many different petroleum provinces in order to do a better job of extracting oil from the ground. You are all familiar with the statistics; of the total known oil-in-place of about 500 billion, we have produced 140 billion barrels, 230 billion barrels is immobile oil, 30 billion barrels are proved reserves and 100 billion barrels are mobile unswept oil. The percentage of mobil unrecovered oil, varies from province to province. However, it is a very large resource. I am concerned with how we bring this very large number into the proved reserve category.

With Shell Oil Company, I guided exploration efforts and was responsible for the technology throughout the United States. Approximately three years ago I made an appraisal of where the oil and gas business was going and at that time it made a lot of sense to me to start going back into the older more mature areas and "digging out" a lot of the remaining oil. In addition, development of gas reserves appeared promising because of recent pricing increases.

To give you an idea of some of our work at Pendleton, we are making plays today in several different portions of Kansas, Ohio, Oklahoma, North Dakota, Illinois and California. All of those plays are shallow oil plays with the exception of California. As we use the term play it usually constitutes an opportunity in which we study and attempt to understand the geology within a given area, in such a way that we are able to define two or more drillable prospects. A prospect is an opportunity to find a new field or to extend an older field. In producing areas and areas where we are doing development and extension drilling we use the same terminology and a play covers an area where we are going to drill many wells.

Let me give you an illustration of one of our current plays. In Kansas there is an area called the Central Kansas Uplift. It is a mature oil province in which most of the drilling was done in the late 1930's and early 1940's during World War II. Most of the major companies did their exploration and exploitation at that time and have left the area in the intervening years. For the past forty years or so only small independents have drilled in that area. Thus, almost no modern technology has been used.

The Central Kansas Uplift is one of the richest areas in the United States in terms of cumulative production over a relatively small area. It has produced three billion barrels of oil to date and to an explorationist it looks like there is nothing left to be done. However, esentially no modern geophysical work has ever been done in that area. All of the work has been done using archaic techniques. Of the 100,000 wells or so drilled in the area, almost all of them drilled only into the top five to ten feet of the formation, tested and, with positive results, set completion pipe and produced. Operators have made their decisions based on no information about the formation itself since they have no logs or other data. When we went into the area two and a half years ago, it was impossible to understand the play technically because the basic research had never been done. We are dealing with a complex carbonate reservoir that is very poorly understood. The result is that we are currently acquiring very high resolution seismic, drilling wells, running sonic logs, creating synthetic seismograms, correlating those back to the seismic lines we have acquired and iterating this process in an attempt to understand the area. In 1987 we drilled 37 wells in the play area. We are doing a type of applied research but the problem is so large that we can't begin to do the research that needs to be done. I understand the Geoscience Institute for Oil and Gas Recovery Research could provide the type of practical research we need today to improve our ability to extract more oil from this province.

There is a thesis that this kind of research is being done in the major companies. Let me start by telling you a story. I was so proud of the first play we put together in Kansas and I felt that it had high potential. I took it to some major oil companies. The first company, Amoco, was quite interested in the play. They went to their files to see what information they had on Kansas and they found a 1952 land map, and no other data. Then I took it to Shell and they had an interested group come to our presentation. Many of the seven people who came were old friends. They were interested in the play and went to their files to check on Kansas. They did not have a single map on Kansas. You can forget about research by major oil companies in these kinds of rocks in the Mid-Continent when the companies don't have the basic data or any interest in the area.

In my opinion, the Central Kansas Uplift has at least 20% more oil remaining to be found by infill drilling, extension drilling with the occasional exploratory outpost well. Twenty percent times three billion barrels is six hundred million barrels barrels and this is a truly significant addition to any major oil company reserve base. But no major oil company will ever make this play because the accumulations will come in hundreds of thousands of barrels or a very few million barrels. Each of these additions will amount to a small volume but added together it will be very large. We drilled thirty-seven wells in this play alone last year. Seventeen of those tests were dry holes which is a waste of money. We did complete twenty. There are many of these types of plays in the Mid-Continent and we need more and better research done in each of these areas.

Let me give you another illustration. We have been able to convince a major oil company, Texaco in this case, to invest with us in Kansas. They are providing funding for us to operate because we can operate for about half or less what it costs them to do the same work. What we presented to them was highly technical work involving seismic resolution of carbonate porosity. Field sizes range from five to twenty-five million barrels of oil at four thousand feet depth. The economics of this kind of play are most remarkable. Texaco recognizes this and bought our concept. Thus far we have drilled two wells, one dry hole and one successful well and the technology seems to be working. But there is much we don't understand about this play and there is the potential for doing a better job if more research could be done in this area.

Texaco is so enthusiastic about our technology that they have come back to us and asked us if we would be willing to take a package of 12,500 miles of seismic data in the Sacramento Basin along with a considerable amount of geologic information that they have and, using our own staff, make a play in that area. What surprises some of the major oil companies is that companies like ours can put together (as we have in this case) technologists who are some of the best in the world into teams to make these kinds of plays. This particular play has two Ph.D. geologists/geophysicists, one masters in geology and three geophysicists from the Colorado School of Mines. It is a first class team.

We presented the Sacramento Basin play in Mobil Oil Company's Research Lab in Dallas on Tuesday of this week, to what I would consider a standing ovation. Our technology has already allowed us to obtain counter proposals from two major oil companies on this project, and I will not be surprised if we get one from two other majors in the next couple of weeks. All of that to say, there are small companies in the exploration and enhanced oil recovery business who are technically proficient.

Our problem is that we have no research base. The usefulness and timelyness of research done by the major oil companies I can summarize with the following illustration. My job for Shell in 1966-1967 was Manager of Geology. At that time we put together some very interesting and significant concepts on how oil is entrapped. That same information was given for the first time last month in a verbal presentation, twenty years after the work was done. We need research now to be applied now to help in both the exploration and exploitation of the very large resource base still present but unaccounted for in the United States.

PANEL 3 DISCUSSION

Mr. **Chapman**. Thank you, Dr. Thomasson. Let me begin, if I may, with some questions in the Eastern oil shale area. I will ask Dr. Rex or Dr. Holland, as the case may be. You have seen the budget recommendations of the Administration for the oil shale programs for fiscal year 1989.

What will happen to the work that you are involved in in the entire program if that budget is adopted? What is the impact; obviously, a 90-percent cut in funds, what does it do for you?

Dr. **Rex**. From HYCRUDE's point of view, we have seen the budget and feel that it is unfortunate. We are happy to see that Congress in past years has supported somewhat of a budget modest funding considering the state of the economy and the deficit.

As far as what it will do to us, it will at this time, stop research in those areas for us. We feel that the modest funding level being supplied is important to have the oil shale resource ready to go when the time comes. We don't see that in the next five years. Probably in the mid-1990's or something around that timespan.

For now it would stop work in that area for us.

Mr. **Chapman**. Based on your experience at this point, and I don't mean to cut you off, Dr. Holland. Please respond to that question.

As an addition to that, I would also invite you to in the longterm looking at the out years, if the research is reduced this year as a part of that answer, what are the long-term implications of this kind of budget reduction on the research effort?

Dr. **Holland**. It would put us dead in the water as far as continuing an effort at our institution. You just need the continuity to maintain your momentum, and a cut of that magnitude even for one year would cause you to lose so much momentum that it would take you two years to gain it back.

Mr. **Chapman**. In the budget resolution for this year, $6 million was included for a research program directed at the Eastern oil shale. Where are you or what is the status of that program at this time, and are either of you participating directly in that?

Dr. **Holland**. We both are. We are participating at about—in our program this year the funding is about $1 million for the first-generation, combination beneficiation and retorting process. A second-generation effort is just beginning. It is in its very early weeks.

Mr. **Chapman**. You have recommended $2.5 million for continuation of that effort, I believe. Beyond that $2.5 million dollars in the budget request you have made some $6 million. Where would you see the balance of those funds being expended?

Dr. **Rex**. As recommended and as in the written testimony, we would like to see another $2 million directed towards the issuance and continuance of the awards that are out there. Also, the $1.5 million for environmental research on some of the new developing technologies.

Mr. **Chapman**. Dr. Fisher, you have recommended an increase of some $20 million. Would you please briefly describe to the extent that you can, how that money would be spent, where the additional funds would go?

Dr. **Fisher**. The recommendation we are making here, Mr. Chairman, is that $20 million would be directed primarily in two areas within the Fossil Energy budget—primarily in enhanced recovery or additional recovery of light oil and for secondary gas recovery—largely because we think those are the real kinds of near-term payouts of the kind that I talked about in my testimony.

That did not necessarily mean any of those to be at the expense of oil shale or unconventional gas or heavy oil recovery. But if we could concentrate on secondary gas —that is simply getting more bypass gas out of existing reservoirs. The same is true of moveable oil in existing reservoirs, if we can begin to develop the kinds of sophisticated models.

The principal expenditure in trying to—one would try to utilize is money. It is primarily in the area of characterizing and modeling, developing advanced models of these old reservoirs so that guys like Ray Thomasson and others can utilize that data and go in for strategic drilling in and around these old fields that many people have long since walked off and given up and particularly some of the larger companies because they are in smaller increments.

There are 60,000 oil reservoirs in the United States. Obviously, no one is going to sit down and begin to characterize and model all of those. That would be forever.

But we think a program that would allow the delineation of type reservoirs—out of certain families—the kind of work that we have done in Texas. If we do that nationally, they allow you to go in and study something on the order of 20 reservoirs.

You would have then representative or typical type situations that you could extrapolate to this much larger universe. We would see most of this expenditure in the area of secondary gas and enhanced light oil recovery, primarily from the standpoint of geological characterization and modeling of existing old reservoirs.

Mr. **Chapman**. Dr. Fisher, explain if you will, should the funding be available to conduct that kind of research, how does that kind of research, how does Mr. Thomasson communicate to those that are doing the R&D and sell you on the Central Kansas uplift where he wants to drill, knowing reserves are there, and how do you transfer from the research that is being done to the private entrepreneur who wants to drill for it this technology?

How do you two communicate with each other in this process as far as getting the Central Kansas Uplift on that list of 120 fields?

Dr. **Fisher**. Sure. There are two main ways we propose to do it. One of the reasons for pursuing this consortium concept of getting everyone together so you have a coordinated mechanism. There will be an advisory committee that is being set up that would include guys like Ray Thomasson and others that will have input into what are the priorities and what is the area.

The second requirement on this thing—we do not want to take a single penny here that we are not prepared to go and match on a 50/50 basis. We will go to guys like Ray Thomasson and anyone else and they will have some of their money in. They will be taking the cost of drilling a research well here. We will be using those data.

The best kind of technology transfer is one where everyone is involved in it directly. We will be working—the idea is working directly across the table with the private sector, with other State entities, as well as DOE.

That's the mechanism for the transfer. We hope it doesn't really involve much transfer other than working on a collective basis.

Mr. CHAPMAN. If you would, can you describe for us moving from the research effort, how that is being conducted? Describe if you would, the consortium concept that has been developed that the Department of Energy has embraced or appears to have embraced, and are we moving toward it, along side—how do those two fit?

Dr. FISHER. One of the principal recommendations that ERAB made last February was that—the obvious thing is that the amount of money that was being spent in geosciences and oil and gas recovery was low. They were quite critical of the lack of coordination of what they referred to as discontinuities within the effort.

I think the attempt of a single consortium has tried to bring together at least in the public sector—the universities and State government—the expertise on a collective basis so we are forced to sit down and resolve our priorities and issues directly.

From that standpoint, I think it accomplishes very much what ERAB was asking to do, at least on the external thing. There is still that issue of how much consolidation or coordination that takes place within the department. I think their proposition of an interagency coordinating group over yonder will give some help in that direction.

The idea of a single consortium is really an expansion, I guess in some ways, of the original recommendation that they made for six centers in the oil and gas producing areas. This would bring in the six plus—really six more entities is about what it involves.

It conceptually is very similar. Their idea of trying to get at a more targeted, more coordinated type of role rather than a fragmented and patterned—they were critical of in the past.

Mr. CHAPMAN. What is the current status of extraction technology, these things you are talking about, and are you in a position to rank the research efforts, the ones that are most promising?

Dr. FISHER. One of the first efforts that the institute consortium will be undertaking, as I mentioned in testimony, will be the development of a comprehensive plan and the establishment of priorities. I could give you my own sense of priority on these things, but what we want is a consensus that would come out of the entire community with the private sector involved to establish those kind of priorities.

I think my—if I can speak from a personal standpoint—you want to look at this in priorities. What is the shorter-term payoff and what is the longer-term type payoff. There, you start looking at the two categories of oil, for example, or natural gas that are in existing reservoirs.

We have got a component of that oil or gas that can be recovered by conventional technologies, extraction technologies if we are smart enough to know where to drill and drill with a high degree of success and hence the efficiencies come in.

In addition to that kind of recovery though the longer term, the much harder-to-get-at oil that we need extraction technologies, advanced ones, whether it be in the different kinds of chemicals in CO_2 or all of the conventional EOR enhanced recovery techniques. You really need both of these.

I would think that prioritization would come in terms of trying to get payout, is to begin to understand reservoirs well enough that we can drill them in a strategic fashion whether you are deploying conventional technology or whether you are employing advanced technologies. If we can do that, it would be very helpful.

We still, Mr. Chairman, drill all reservoirs and Dr. Thomasson will tell you this too—we drill them on a uniform acreage spacing. I mean, we step off every 40 acres or every 80 acres or what. We are really talking about the makeup of these reservoirs is much more complicated. If we can drill a little more concentrated here and less here, more concentrated here and do that more strategically, then there comes inefficiency.

He drills fewer dry holes, he drills more producing wells or more highly productive wells and that efficiency allows a much bigger part of this 100 billions that we are talking about to be accessed.

Mr. CHAPMAN. In the 1989 budget request to the Administration for Fossil R&D, there's a $9 million line item for what is called cooperative venture programs. It is aimed at cost sharing smaller oil and gas projects.

Do you have any opinion as to what kind of projects would fit into that $9 million program?

Dr. FISHER. Some of the very kinds of programs that we are talking about in this area could very well be the kind of fit that would come in that cooperative venture. Whether they are put together or not, that's another point.

I think Mr. Webb will be making some reference to at least one proposition we have underway, where the secondary gas recovery utilizing the mechanism of the cooperative venture thing. Conceptually, what we are talking about through a consortium or what these cooperative ventures are, are really quite similar. They all seek to involve participation of a funding mix that is State, Federal and private and in that same process get the best expertise of all areas and have a much more targeted, much more consensus type of research going on.

Mr. CHAPMAN. Does there need to be that separate line item, or should that be a part of the pool for perhaps the other projects, the other research that you have described should be undertaken as part of DOE's program?

Dr. FISHER. I think ideally most people in the community would like to see as much of these issues handled in straight and specified lines as possible. Whatever the budget constraints for process may or may not be on this, that could certainly be tied into the same kind of line of what we are talking about.

Conceptually, the administrative structure of the research and the focus of it is quite similar. So there would be—there is no barrier from that standpoint. If there is one from just the budgeting process, well that's another issue, Mr. Chairman.

Mr. CHAPMAN. Thank you, Dr. Fisher. We have been joined by Sid Morrison as well as my colleague from Texas, Congressman Hall. I would like to recognize Congressman Morrison at this time.

Mr. MORRISON. Thank you, Mr. Chairman. I am frantically trying to read through the testimony to catch up with having missed the panel, so I won't ask any questions at this time.

I would like to be able to submit them in writing, if that is permissible.

Mr. CHAPMAN. Without objection. I was derelict in recognizing my colleague from Connecticut, Mr. Shays. Mr. Hall, do you have any questions at this time?

Mr. HALL. Mr. Chairman, I will also submit questions in writing, inasmuch as I was unable to be here.

Mr. CHAPMAN. Without objection.

Mr. HALL. I think, Mr. Chairman, if I am yielded I will take part of it to brag on Bill Fisher because he is not a stranger up here. Not to diminish the importance and generosity of these other gentlemen, who are apparently very recognized and very appreciated and evidence their willingness to give by being here.

Mr. Chairman, I think it should be pointed out that the empty desk here should connote that we are very busy up here and not a lack of interest. Your testimony will be recorded and all will get it. The staff will get it and then they will explain it to us. [Laughter.]

I think certainly, Bill Fisher who is the Chairman of the Bureau of Economic Geology at the University of Texas and also serves as a State geologist, he is the guy that has one foot planted in academia and the other foot planted in the State house.

Regardless of party, he is a highly-regarded man down there. Through testimony, advice and guidance like your's, that we are going to find some energy solutions that we are really looking for. Other than Bill, you might tell us about some of your experiences that you have had in the operation out in West Texas where the University has increased the yield I think dramatically. Was that in Yates?

Dr. FISHER. It involved primarily San Andreas, Grayburg, some of those very complicated reservoirs in the Permian Basin. I mentioned a little of that in my testimony, in terms of as a demonstration of the kind of immediate shorter term payout that come from these kinds of targeted research.

In those particular cases, the work in West Texas that we did there, the University of Texas as you know Congressman, is a royalty owner. The leases are privately operated by a variety of operators, from major operators down to small, independent operators.

We are doing the research in support and the geological modeling work was supported by the Board of Regents but working directly with the operators. So it was the operator that went and deployed it. We came up with a concept and idea working with that operator, previously using that operator's data that they would have available to it, and then that operator would then go drill a well and prove it out.

That's why we wound up proving up the resources. That is the very same thing that Ray Thomasson was talking or the Chairman was talking about in trying to transfer the technology. The best way to transfer it is working directly with all the entities involved.

If it is a good idea and you get it tested, you know whether it's a good idea—that's the reason we had the kind of payback and we can demonstrate the kind of payback on that West Texas. Otherwise, we would be writing reports and waiting for how long until someone read it. And then we wouldn't necessarily know who read it, what they did with it and the like. That kind of close working is critical, I think.

Mr. **Hall**. I surely am pleased that the Department established the Office of Geoscience Research and that Secretary Wampler has evidenced his intent, I think, by signing a letter of intent to support the recently created Geoscience Institute for Oil and Gas Recovery Research.

Dr. **Fisher**. That's right.

Mr. **Hall**. I believe that will certainly ensure that Federal contributions will be well utilized. Hopefully, it will bear some fruit. I sure thank all of you gentlemen.

Inasmuch as I didn't hear your testimony and have not had the opportunity to read it, we will probably have some questions we would ask you to enlarge on and ask you for that much more of your time.

Mr. Chairman, I yield back the balance of my time.

Mr. **Chapman**. Thank you, Mr. Hall. Let me conclude with this panel by simply thanking each of you for taking times out of your schedule to come here. As Congressman Hall said, this Committee is vitally interested in the work that you are about and the endeavors that you are engaged in.

Some of us believe that there are some misplaced priorities in the energy R&D budget, which I understand the total exceeds $3 billion for everything and we are spending whatever this meager pittance is in what I think is a matter not just to do with energy independence but literally is a crucial national security issue.

We appreciate the work that you do, in that we are going to do everything that we can do to support that from the standpoint of our budget efforts. I hope that we will be able to alter the Administration's recommendation in this area to reflect a little bit increased priority in the work that you gentlemen do.

Thank you gentlemen, for being here today.

Dr. **Fisher**. Thank you, Mr. Chairman.

Dr. **Rex**. Thank you, Mr. Chairman.

[Questions and answers for Panel 3 follow:]

Reply to Congressman Lamar Smith's Questions Related to Dr. W. L. Fisher's Congressional Testimony, March 3, 1988

Question 1A) How will the Institute use that additional funding, and what expectations should we have for new knowledge and techniques developed through the Institute that will enable us to increase recovery of currently movable and residual oil?

Establishment of the Geoscience Institute for the first time provides a mechanism for development of a nationally coordinated public sector research effort focused on oil and gas recovery. Participation in the Institute will allow the most advanced petroleum engineering, geophysical, and geological groups in the public sector to come together and work in a collaborative fashion to address key technical oil and gas recovery issues. Funds made available to the Institute and its participants will be matched on a one-for-one basis, resulting in national annual effort of up to $40 million.

Despite the current need to stabilize and increase domestic production, the U.S. is abandoning more than 300 billion barrels of unswept oil in existing known fields. The payback from the geoscience program will be improved recovery of the unswept oil and gas reserves that constitute the largest domestic hydrocarbon resource potentially convertible to producible reserves in the U.S. today. This U.S. oil resource, bypassed or trapped in the rock after today's technology has been efficiently applied, is of two types. It is estimated that nearly 100 billion barrels of mobile oil, unswept by conventional field development practices, occur in known existing fields.

During the past decade, unswept mobile oil has been the principal source of reserve additions and continues to be a significant target for future reserve growth. These reserves are producible if new geoscience-based, targeted infilling drilling technologies can be developed in a timely fashion to locate, contact, and properly flood the reservoir. Provided new advanced technology is developed and available for wide industry application, the projected recovery of these conventionally recoverable mobile oil reserves is expected to continue to provide the largest target of low to moderate cost oil reserves available to the domestic industry.

In addition, over 200 billion barrels of immobile "residual" oil are trapped in reservoirs by viscous and capillary forces. This huge resource of immobile oil can be partially recovered through improved geoscience targeting and application of new advanced tertiary recovery technologies. This immobile oil resource requires oil prices to be in a minimum range of $30 to $50 barrels to make recovery of these reserves economically feasible.

The Institute proposes to formulate a comprehensive multidisciplinary research program that provides for the development, testing, and application of new technologies required to bring on stream unswept mobile and immobile domestic oil resources. The plan will focus on, but not be limited to, new technological developments in the five following major research areas:

- Improved Geological Characterization and Modeling of Reservoir Heterogeneity for More Efficient Recovery
- Development of a National Reservoir Play Analysis for the Delineation of Unrecovered Oil and Gas Reserves

- Development of New Techniques for Improved Delineation and Analysis of Subtle Stratigraphic Traps and Complex Structural Traps
- Improved Surface and Borehole Geophysical Tools for Reservoir Characterization and Framework Delineation
- Development of Advanced Oil and Gas Extraction Process Technology for Increased Recovery

New technological improvements and breakthroughs in these areas of research emphasis will have a significant impact on improving our ability to stabilize and reverse declining domestic production rates. By way of example, in 1984 the University of Texas Board of Regents established a research program at the Bureau of Economic Geology to characterize and geologically model oil reservoirs on lands in West Texas held by the University. The research was targeted directly to identifying additional conventionally producible mobile oil. To date, with a research expenditure of $2 million, some 65 million additional barrels of unswept oil have been delineated in old, existing reservoirs by the project. Some of these reserves have already been produced, and some are now under development. Assuming that only one-third of the reserves delineated is ultimately produced, at an average value of $20 per barrel, a conservative assumption, the University as royalty owner will receive a return on its investment of 27 to 1.

If we extrapolate the University Lands results nationally but assume a success only one-quarter of that achieved in the University Lands program, an annual $20 million research investment would result in a localization of some 160 million barrels of oil. The net national benefit of a barrel of oil produced domestically has been calculated in the literature at a range of $2 to more than $100 per barrel. However, a conservative calculation by Professor Bill Hogan and his associates at The Energy and Environmental Policy Center at Harvard placed the value at $11 per barrel. If one-third of the 160 million barrels resulting from the $20 million research investment is ultimately produced, the public return on the investment would be nearly 30 to 1.

A long-term 15- to 20-year oil and recovery research program as proposed by the Institute will help stabilize our domestic production and reduce our need for oil imports into the next century. We believe our projections for new reserve growth through improved and advanced technological applications are optimistically conservative. In order to attain the projected results, a long-term program with a continuity of base funding on the $20 to $30 million level is required.

Question 1B) How will West Texas, specifically Midland, be involved with the Institute? Will the Institute invest any funds in research and development in the Permian Basin area?

It is estimated that 35 billion barrels of unrecovered mobile oil will remain in Texas reservoirs at abandonment. Almost three-quarters, or 25 billion barrels, of this resource are in West Texas reservoirs in the Permian Basin. Institute research efforts will focus on this resource by building on existing programs that are attempting to develop recovery strategies for this large volume of West Texas crude oil. The Bureau of Economic Geology already has several projects in place evaluating this resource. The largest of these is a $500,000 per year effort aimed at improving recovery from University of Texas System Lands. A second project (funded to the level of $270,000 over a two-year period) is attempting to help operators drill wells more efficiently to recover more oil from low-recovery deep-basin sands in the Midland Basin. A new third project presently being developed, based on funding from a group of industry affiliates, is planned to examine reservoir properties of the prolific San Andres Formation that spans the entire Permian Basin area. These current projects could all be expanded by matching funds from the Geoscience Institute.

Studies already in place are designed to support the development activities of West Texas operators ranging in size from major oil companies to the large number of independent operators in the Permian Basin. These efforts indirectly support property owners through increased royalty income by lengthening the period of production. In addition to working directly with the operators, results of our studies are transferred through public workshops and forums in petroleum centers such as Midland and Amarillo and through interaction with personnel of the University Lands Office in Midland. We are also exploring avenues for new collaborative research efforts with the University of Texas, Permian Basin, the Permian Basin Graduate Center, and the newly created Center for Energy and Economic Diversification.

With increased funding through the Institute, these ongoing projects could be significantly increased. We do not lack new ideas for oil and gas recovery research projects. Our program effort in the West Texas area is limited by funding level and not project opportunities.

Question 2) What would you recommend that the Office of Geoscience Research do to promote a coordinated plan for oil and gas recovery research? What should the focus of their plan be?

The Office of Geoscience Research (OGR), as urged by the Congress and as established by the Department of Energy, is a critical first step in coordinating the existing, rather disparate geoscience research efforts in the Department. The Geoscience Institute, working through the Office of Geoscience Research, can develop a coordinated plan. However, for the Office to be effective, the several geoscience program efforts in Fossil Energy should be rolled into a single line appropriation to the OGR. The Committee may want to ask the Department for a breakdown as well as the advantages of consolidation. In addition, I recommend an incremental funding of $20 million be appropriated for the line with an earmark to the Geoscience Institute. Any funds made available to the Institute would be subject to program approval by the Department and be subject to 50/50 matching by recipients. These several actions would give a national geoscience effort of nearly $50 million, which, when conducted through the OGR and the Geoscience Institute, will have a significant impact and will provide a positive public return.

The research plan, in my judgment, should concentrate on oil and gas recovery research with both short term and longer term returns. This would emphasize the development of advanced geologic models for increased and efficient recovery through strategic drilling, as well as emphasize advanced extraction technologies to be deployed based on the developed models.

Question 3) What does the current low price of oil do to the economics of enhanced oil recovery?

Oil price significantly impacts EOR economics and potential ultimate recovery of immobile reserves. At the present $15 to $18/barrel price plateau, except for a few thermal recovery units already operational, EOR projects are noneconomic. The National Petroleum Council (NPC) has estimated that at $20/barrel the ultimate EOR is approximately 7.5 billion barrels. Economics for significant EOR payback are not "right" until oil prices reach the $30 to $50/barrel range. At $30 to $40/barrel, it is estimated an additional 32 billion barrels could be recovered, and a $50/barrel price would provide for an incremental recovery of 19 billion barrels. These observations are summarized in NPC's June 1984 Enhanced Oil Recovery publication.

The bottom line is industry will not be willing to make the major capital investments in EOR projects until oil prices stabilize in the $30 to $50/barrel range. Only then can we expect to see appreciable incremental immobile oil production help reduce the flow of foreign imports. Of course, Federal tax incentives related to start-up and operation of EOR projects could also favorably impact such ventures, the same as oil price. However, now is the time to press ahead on the research front in order to improve our process recovery technology for rapid application when the economics are right.

Republican Member Questions for the Record
for the Hearing of March 3, 1988, for
RAYMOND C. REX, JR., HYCRUDE CORPORATION

1. What is the proposed schedule of the pressurized fluidized-bed hydroretorting (PFH) process R&D program?

   The currently contracted development program is scheduled to take three years, from September 30, 1988 through September 30, 1990.

2. What is the cost to completion of the PFH process R&D program?

   The currently contracted research and development program is expected to be completed at a cost of $6.5 million.

3. What is the relationship between HYCRUDE Corporation and IGT?

   HYCRUDE is a subsidiary of Gas Development Corporation, which is a subsidiary of IGT.

PANEL 4: GAS R&D

Mr. CHAPMAN. Thank you. Our next panel consists of representatives of the gas industry. They are Mr. Mike Baly, representing the American Gas Association, who has appeared here many times before; Mr. David Webb of the Gas Research Institute; Dr. Bernard Lee, Institute of Gas Technology; and Dr. Vernon Jones, representing Interstate Natural Gas Association of America.

Gentlemen, I welcome you to this Committee hearing. I don't believe that there is a stranger to this process among you, so you know the drill. With that brief introduction, Mike if you would like to begin, we would be pleased to hear from you.

Again, let me remind you if you would, please summarize your comments and try to abide by the five minute rule of the Committee.

STATEMENT OF MICHAEL BALY III, VICE PRESIDENT, GOVERNMENT RELATIONS, AMERICAN GAS ASSOCIATION, ARLINGTON, VA

Mr. BALY. Thank you, Mr. Chairman, Congressmen Morrison, Hall and Shays. I am Mike Baly, Vice President of the American Gas Association. With me is Bill Travers, our manager of Energy Technology Development and a loan executive from New York State Electric and Gas Company.

Our country needs an adequately-funded DOE research program not only to meet future energy needs, but also to remain competitive in today's world economy. Gas-related research may be the most important component of DOE's research program.

The gas industry can make two major contributions to the competitive performance of U.S. manufacturing and industrial companies. One, natural gas is for most uses a more economic and efficient fuel. Two, new highly-efficient gas-fueled electric generation will improve the economy of electric energy. AGA along with GRI, IGT and INGAA, recommend an authorization of $114 million for all DOE related R&D, which is slightly less than last year's request.

We commend you, Mr. Chairman, and this Subcommittee for its foresight in restoring by almost three-fold, last year's DOE cuts. We recognize that the continuing budget deficit places severe restraints on Federal energy research dollars and makes your job a tougher one.

Over the last two years, we at this table, have pared back our recommendations requesting instead funding for only those technologies that are essential and prudent for the orderly development of new domestic gas supply and utilization technologies.

We urge the Subcommittee to adopt our "bare bones" research recommendations—I believe you used the word pittance, Mr. Chairman—to help this nation move toward achieving its environmental and national security goals. We are pleased that DOE several weeks ago, announced a major demand and supply study for natural gas. We hope that their next step will be support of your gas supply related research.

The gas resource base is several times larger than the presently recoverable gas resource base. In a recent study of gas use in 14 industrialized nations around the world, 11 of the 14 have significantly increased their use of gas. Only three declined. The U.S. was one of them with a decline of 8 percent. Worldwide gas use was up 31 percent; Russia rose by 91 percent. So we feel it is time for America to see what other nations already see, that natural gas is an ideal choice to fuel energy self-sufficiency.

This Subcommittee, with your help by authorizing 20 percent more R&D dollars last year for unconventional gas recovery, has reversed Congress' long-term downward trend on R&D funding. We hope you will be able to continue this upward trend.

We commend this Subcommittee for supporting a stronger geosciences program. AGA believes that it is of the utmost importance for DOE to fund $10 million for geosciences to implement the ERAB report of last year. We recommend $65.45 million for the total fossil energy R&D, with $20 million for unconventional natural gas.

The unconventional gas recovery we feel would have the largest rate of return, resulting in an annual additional production of up to four trillion cubic feet by the year 2000 compared to the current trend of only an additional one TCF in that year.

We recommend $5 million for coal seam gas recovery to augment the GRI funding of $6.5 million, in the development of this technology. Our conservation and renewable requests are described in my written statement. We recommend a total authorization of $29 million to further increase development of efficient end-use technologies such as the gas heat pump, cogeneration, and natural gas-fueled vehicles.

I had the privilege several weeks ago of appearing on the Texas Capitol steps along with the Texas Land Commission and the Texas Railroad Commission and the Mental Health Agency, to announce that they were going to be converting their fleet vehicles to natural gas and use that savings for education programs. So we think more can be done there.

Lastly, the geopressured methane program is vitally important to our country. We would hope that DOE would redirect its research efforts, concentrating more on getting the dissolved methane than focusing on producing gas and electricity from low grade heat.

Let me thank you again, Mr. Chairman, for your support of a more balanced R&D program.

[The prepared statement of Mr. Baly follows:]

TESTIMONY OF MICHAEL BALY III
VICE PRESIDENT, GOVERNMENT RELATIONS
AMERICAN GAS ASSOCIATION
BEFORE THE SUBCOMMITTEE ON
ENERGY RESEARCH AND DEVELOPMENT
COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY
UNITED STATES HOUSE OF REPRESENTATIVES
ON THE FY 1989 DEPARTMENT OF ENERGY
RESEARCH AND DEVELOPMENT BUDGET
MARCH 3, 1988

Mr. Chairman and Members of the Subcommittee.

I am Michael Baly III, Vice President of Government Relations for the American Gas Association (A.G.A.). The American Gas Association is a national trade association comprised of some 250 natural gas distribution and transmission companies serving over 166 million natural gas consumers throughout the United States. I am pleased to appear before you in support of natural gas-related research and development (R&D) conducted or sponsored by the Department of Energy (DOE).

The natural gas industry recommends an appropriation of $114.35 million for all DOE gas-related R&D in Fiscal Year (FY) 1989. This total is broken down as follows: $65.45 million for fossil energy R&D; $29.0 million for conservation R&D which includes $5.0 million for a natural gas vehicle R&D program; and $19.9 million for renewable energy R&D, which includes $1.5 million to administer the liquid spill test facility in Nevada.

THE IMPORTANCE OF GAS-RELATED RESEARCH

The United States needs an adequately funded DOE research program not only to meet future energy needs, but also to remain competitive in today's world economy. Gas-related research may be the most important component of DOE's research program.

Natural gas has an important future role because its attributes favor its use in a myriad of applications. First, gas is the cleanest of all fossil fuels. Natural gas contains virtually no sulfur. In contrast, the sulfur content of coal and oil range up to seven and five percent, respectively. Further, gas combustion emits less nitrogen oxides and hydrocarbons than other fossil fuels. Moreover, gas combustion does not create ash and sludge that must be disposed. Indeed, the air pollution problems resulting from the combustion of other fossil fuels has caused many in Congress and the Administration to call for solutions to the ozone nonattainment and acid deposition problems facing the nation today.

Second, natural gas can be delivered quickly, efficiently and without major environmental impact, through the existing million-mile transmission and distribution system.

Third, natural gas can be converted into usable energy more efficiently and inexpensively than other fossil fuels. The efficiency of current gas utilization technologies ranges from 98 percent for residential heating to 70 percent for industrial cogeneration and 50 percent for combined cycle turbine systems for electric generation.

With these attributes, there is little question that natural gas will play an important role in the nation's energy future. Indeed, today, natural gas can be used in almost any application without adverse environmental ramifications. Gas is used for space heating and cooling, cooking, water heating, clothes drying, electric generation, and as a chemical feedstock. It also serves to generate steam for industrial process requirements.

Gas can be used for pollution control to reduce sulfur and nitrogen oxide emissions of other fossil fuels. Gas can be used as a vehicular fuel. No other single fossil fuel can be used in as many applications as natural gas without major negative environmental consequences. Given the multitude of uses natural gas can serve, DOE should invest more money, not less, on gas-related research.

DOE's role in gas research serves two very important purposes. First, DOE's support of gas supply-related research will ensure the recovery of a larger percentage of the total gas resource base. The total gas resource base is several thousand times larger than the presently recoverable gas resource base. The amount of gas that may be recovered from the total gas resource base is directly contingent upon our ability to develop new tools and techniques to recover this gas at commercially viable prices.

With foreseeable technology and economics, there are 630 Tcf of potential conventional resources in the lower-48 states alone. When 159 Tcf of proven reserves are added to this number, the lower-48 states have the equivalent of about 50 years of conventional supply at 1986 production levels. Technological breakthroughs are necessary to increase long term gas supplies dramatically. Federal funding is necessary to develop the long-term, high-risk technology base necessary to achieve these breakthroughs.

We are pleased that this Committee and Congress has recognized the importance of gas-related research. By appropriating 20% more research and development dollars in FY 1988 than FY 1987 for unconventional gas recovery, Congress has reversed a long-term downward trend in R&D funding. We hope this trend will be continued.

We are also pleased that this Committee has recognized the need for a stronger geosciences program, as evidenced by the hearing held by this Committee last summer and the comments made by many members. A.G.A. believes that it is of the utmost importance for the Department of Energy to reevaluate its basic energy research goals and implement a hydrocarbon geoscience research program based on the ERAB recommendations presented in its February 1987 report to DOE, "Geoscience Research for Energy Security." Therefore, to enhance the current move toward a geoscience program, we recommend that DOE commit to geosciences research $10 million of the FY 1989 funds slated for unconventional natural gas.

Second, DOE funding is needed to radically change the manner in which we use gas. For example, further research on electrochemical processes and thermodynamics could improve the process for transforming gas into usable energy, with greater efficiency and no environmental impact. DOE can and must play a central role in gas technology development, in order for the U.S. to reduce its reliance on foreign oil, improve its energy efficiency to enable industry to compete in the global marketplace, and reduce pollution.

SPECIFIC FUNDING RECOMMENDATIONS

FOSSIL ENERGY R&D: $65.45 Million

(1) Unconventional Natural Gas ($20 Million)

Large amounts of gas have been identified in tight geological formations such as Devonian shales and tight sands. Devonian shales and tight sands are estimated to contain more than 1,800 Tcf and 900 Tcf of gas, respectively. Tight formations gas is produced using unconventional recovery techniques. A.G.A. estimates that favorable economic conditions and substantial investment in tight formations R&D programs could result in annual "incremental" production of up to 4.0 Tcf of gas by the year 2000, while the current rate of technology would produce approximately 1.0 Tcf by that year.

In order to optimize the amount of gas recovered from unconventional sources, basic geoscience research must be expanded. This research should be aimed at increasing our knowledge of the geological/geochemical/geophysical characteristics and parameters of both conventional and unconventional formations. This cross-cutting, reservoir characterization-type research is essential to both exploration and production in new formations (characterized by subtle traps) and using secondary recovery techniques in existing fields.

Moreover, because of the potentially enormous size of unconventional gas resources (e.g., gas hydrates and deep source gas), extensive research is necessary just to verify how much may be technologically and economically recoverable.

To enhance the technology of recovering the gas from unconventional gas resources, more research must be conducted to develop advanced stimulation techniques to fracture tight rock formations that restrict gas flow. Current fracturing techniques induce only shallow fractures of a few hundred feet. Field testing must be conducted to refine techniques for inducing deep fractures of several thousand feet. Such techniques include gas/liquid injection, foam, cryogenic, hydraulic, chemical explosive, and high energy gas fracturing. Also, research information must be collected from field testing to establish a technological database for stimulation modeling, economic modeling and other analytical purposes.

In addition, advanced drilling techniques (directional and horizontal) must be refined and improved to increase production rates and reduce drilling costs.

(2) Surface Coal Gasification ($15 Million)

Surface coal gasification is an important technology that can augment future natural gas supplies. A.G.A. projects that, by the year 2000, surface coal gasification has the potential to contribute approximately 100 billion cubic feet (Bcf) of additional gas supplies. However, with vigorous R&D support, surface coal gasification could contribute up to 200 Bcf to our supplies.

Contemporary technologies allow significant production of gas from coal; however, substantial research into the gasification process is necessary for synthesized gas from coal to play a role in meeting this nation's future energy needs. Gasification techniques must be developed to accommodate high-sulfur Eastern coals and combustion-inhibiting coal "fines." Research must be conducted to develop techniques for gasifying these "fines," for disposition of liquid byproducts, and for consolidating "fines" and tars for utilization.

Scientific and engineering feasibility studies of advanced generation gasification processes must also be conducted to develop a technological database for such processes. In addition, research must be conducted to identify the proper treatment and disposal techniques for gasification waste byproducts.

(3) Fuel Cells ($22.7 Million)

Gas-fired fuels cells, in a highly efficient electrochemical process, convert the energy content of gas directly into electricity and byproduct heat. This process is much more advantageous than current electrical generation technologies, which rely upon the less efficient combustion process to generate electricity. The electrical conversion efficiency of gas-fired fuel cells is approximately 15-20 percent greater than the conversion efficiency of traditional electrical generation. Combining fuel cells with certain cogeneration applications could achieve combined electrical and thermal conversion efficiencies of 80 percent, compared to conversion efficiencies of 30-35 percent by the conventional electric utility. Fuel cells are also environmentally benign, emitting virtually no pollutants. As work on the phosphoric acid fuel cell reaches its conclusion, the gas industry's focus is directed toward the development of advanced fuel cells.

Molten carbonate fuel cells operate at higher temperatures and are more conducive for industrial applications. Research must be conducted to develop second-generation molten carbonate fuel cells capable of processing gases containing various impurities, as well as to develop other advanced, direct conversion concepts, such as solid oxide and proton conductor fuels cells. The second and third generation fuel cell concepts are still years away and therefore, dependent upon federal R&D support to supplement industry efforts.

(4) Underground Coal Gasification ($1.75 Million)

Underground coal gasification is the process whereby coal is burned underground, in formation, generating a low-Btu or medium-Btu gas. The coal is gasified by drilling boreholes into the coal seam, igniting the coal and injecting air, steam or oxygen into the reaction zone. The hot gas is forced through the seam to an exit borehole where it is carried to the surface and processed to remove impurities. The gas can then be used directly as an energy source or can be upgraded to pipeline quality through catalytic methanation and subsequent gas processing.

Underground coal gasification could substantially increase the coal resource base, 93 percent of which presently cannot be recovered economically using conventional mining techniques. Moreover, underground coal gasification offers potential environmental, economic and safety advantages over conventional mining.

Extensive field testing is necessary to understand the technological basis for linking the vertical wells through the coal seam and controlling the movement of the reaction zone. Extensive environmental monitoring is also required to analyze and control the potential contamination of surface water and local aquifers, and to control surface subsidence.

To date, DOE sponsored field tests of the controlled-retracting-injection-point (CRIP) technology have been conducted in the Western United States. This technology now needs to be tested and demonstrated on Eastern bituminous coals.

(5) Advanced Research & Technology Development ($6 Million)

The Advanced Research and Technology Development program generally provides a technology base for ongoing fossil energy projects and for advanced process development. Current research needs include: improving the understanding of the interactions of coal gasification processes in a fluidized-bed environment; improving the understanding of the interaction of gasification catalysts with carbon/steam and carbon/hydrogen reactions; developing advanced processes for low-cost synthesized gas; developing lower-cost acid-gas cleanup processes; and continuing efforts to assess advanced cleanup technology for alkali metals, particulates and tars.

CONSERVATION: $29 Million

(1) Gas Heat Pumps ($7 Million)

The operating principle of a heat pump is very similar to that of a common refrigerator, freezer or air conditioner: it removes heat from a source and pumps it to its destination. By extracting heat from the outside air and transferring it to the indoor space, heat pumps can actually supply more thermal energy than is contained in the fuel that they use. The heat pump's cooling effect is accomplished by reversing this process. The gas heat pump provides heating and cooling in a single unit using less energy than a conventional or high efficiency furnace uses for heating alone. Current performance estimates suggest that in heating, the gas heat pump could save one-half of the gas used in a conventional furnace and one-quarter of the gas used in a high efficiency furnace.

More research is necessary to develop highly-efficient, reliable and cost-effective gas heat pumps for residential and commercial applications. In order to improve durability, maintenance and endurance, such research must include the evaluation of promising technical approaches, fundamental research in basic heat pump concepts, processes, phenomena and materials, and research on generic component development. These activities must be integrated into overall heat pump system development and analysis. Presently the most promising gas heat pump concepts are the dual cycle absorption concept, absorption technology using fluids in novel cycles, and engine driven concepts using available and emerging internal combustion technology.

(2) Industrial Cogeneration ($5 Million)

Gas-fired cogeneration can supply both electrical and thermal energy service in a highly efficient manner. The environmental benefits of gas-fired cogeneration are also significant, since the efficient use of clean-burning gas decreases total emissions. A coordinated federal/industry cogeneration research program focusing on cogeneration of electricity or shaft horsepower and useful heat could produce overall efficiencies of 70 to 80 percent. New approaches that meet the combined thermal, shaft horsepower, and electrical requirements of an industrial facility are needed. The major problem is to develop and build advanced systems with improved qualities for longevity, operating efficiencies, and ease of maintenance.

The DOE's research should focus on developing advanced materials and advanced heat transfer, thermodynamic and microprocessor control concepts. These components and concepts must then be integrated into prototype units to allow industry to evaluate the effectiveness, efficiency, reliability, and flexibility of cogeneration systems. The result is increased cost savings and expanding potential applications for gas-fired cogeneration systems. Improved components from this DOE-sponsored research can be integrated into both first- and second-generation packaged cogeneration systems.

Cogeneration R&D targeted at increasing engine performance, extending component durability and developing advanced control systems, will result in smaller, more compact cogeneration systems that are quiet, environmentally sound, and that recover higher quality heat. Since most commercially available prime movers and ancillary components on the market today are designed for uses other than cogeneration much work is needed. Also, because the continuous operation of cogeneration units makes life-cycle operating and maintenance costs especially significant, more research is needed to increase the reliability and efficiency of these components.

(3) Natural Gas Vehicles (NGVs) ($5 Million)

Broad development of vehicles fueled by compressed natural gas would serve the national interest by improving air quality, since the emissions from natural gas vehicles (NGVs) contain only a fraction of the nonmethane hydrocarbons, carbon monoxide, and nitrogen oxide produced by gasoline-powered vehicles. Furthermore, unlike gasoline-powered vehicles, NGVs emit almost no sulfur oxides or particulate matter. Fleet use of NGVs in congested cities would provide a significant benefit to those areas where air quality improvement is most critical. Furthermore, substantial potential exists for emissions reductions from diesel engines through the use of natural gas/diesel fuel mixtures in those engines.

Conversion to partial or dedicated natural gas/heavy duty diesel engines holds the promise of a low-emissions engine, but R&D is required to address the well recognized technical difficulties. Moreover, the technology forcing EPA particulate emissions standards effective in 1991, make development of advanced, dedicated NGVs imperative.

Fundamental research is necessary to acquire a thorough understanding of the intricacies of gaseous fuel injection, carburetion, manifolding, combustion, power optimization and emissions control so that natural gas can become broadly accepted as a transportation fuel. Further research into novel gas compression concepts is necessary to advance the development of compressor technology. Research must also be conducted on advanced storage systems (e.g., sorbent materials) to increase the understanding of gas storage technology, particularly the fundamental principles of natural gas adsorption, absorption, clathration and catalysis.

Other research projects that are included in our conservation recommendation of $29 million are: (a) $3.0 million for DOE research on indoor air quality; (b) $7.0 million for tribology, ceramics, and other materials-type research for the energy conservation utilization technology program (ECUT); and (c) $2.0 million for research on desiccant technology which is used in gas cooling.

RENEWABLE ENERGY: $19.9 Million

(1) Geopressured Methane ($10.4 Million)

Geopressured methane is found in either a free state or dissolved in water and trapped in sedimentary rock at higher-than-normal pressures. One of the largest geopressured areas underlies a portion of the Texas and Louisiana Gulf Coast. Estimates of the total resource in-place range up to 100,000 Tcf; however, estimates of the amounts of gas that might ultimately be recovered, given current recovery techniques, range between 25 and 1,200 Tcf. If technological breakthroughs can be achieved, geopressured methane could become a virtually inexhaustible source of domestic energy.

Research conducted by DOE in geopressured/geothermal zones is focused on producing both gas and electricity from low-grade heat in the reservoir brine. DOE should redirect its research efforts and concentrate more on recovering the vast amount of dissolved methane found in geopressured zones. In addition to DOE's current geopressured program, DOE should develop new approaches that utilize traditional engineering principles to maximize gas production and minimize brine production.

(2) Biomass ($8 Million)

Since the supply of organic and waste materials is virtually unlimited, supplemental methane supplies from biomass and waste conversion can add significantly to the total future gas supply picture. Developing energy from biomass also would promote the environmental benefit of productive use of currently "useless" materials. However, the quality of the gas produced and a suitable processing technique are important concerns that inhibit the widespread use of these potential gas resources.

The sources of biomass, land and marine plant matter, must be tested to determine the appropriate technology for producing high-quality gas from the resource. Because these sources vary greatly in content, the technologies must be flexible. To produce gas economically, processing techniques must be improved to increase conversion efficiencies. This can be accomplished by providing adequate funding to ensure continuity of long-term, high-risk R&D programs.

(3) Liquefied Natural Gas Safety ($1.5 Million)

Liquefied natural gas (LNG) is natural gas that is converted into liquid form by reducing its temperature to minus 260°F. This technique is advantageous because it permits large volumes of natural gas to be transported by truck or ship over great distances and terrain not suitable for pipelines. Potentially, the resource base for LNG includes any overseas gas reserves beyond those required for local consumption. However, one difficulty with transporting LNG has been that more definitive experimental data is needed on the behavior of large spills.

The Liquefied Gaseous Fuels Test Facility in Nevada allows researchers, on a user fee basis, to evaluate spills of liquefied gases, including LNG, at magnitudes far greater than have been previously possible. The research needs include: investigating equipment vulnerability to natural forces, the ability of dikes to contain large spills, the advantages of in-ground storage; the behavior of spills on different surfaces (soil and water) and the validation of methods for preventing accidental liquefied gaseous fuels spills.

CONCLUSION

The natural gas industry recognizes that the continuing budget deficit places severe constraints on federal energy research dollars. Over the last two years, we have pared back our recommendations, requesting instead funding for only those technologies that are essential and prudent for the orderly development of new, domestic gas supply and utilization technologies. If Congress adopts our research recommendations, the nation will, over the long term, improve its energy supply security and energy efficiency.

Mr. CHAPMAN. Thank you, Mr. Baly. Mr. Webb, you may proceed.

STATEMENT OF DAVID O. WEBB, SENIOR VICE PRESIDENT, POLICY AND REGULATORY AFFAIRS, GAS RESEARCH INSTITUTE, WASHINGTON, DC

Mr. WEBB. Thank you, Mr. Chairman and Members of the Subcommittee. I appreciate the opportunity to appear before you today to present GRI's fiscal year 1989 budget recommendations for gas-related research and DOE's Fossil Energy Programs.

In developing these recommendations, GRI and the gas industry balanced two conflicting priorities. One, the need to reduce Federal expenditures, while at the same time the need to maintain essential research to reduce the Nation's vulnerability to imported oil. In this light, GRI and the gas industry recommend a total of $114 million, of which $67 million is for gas-related research in the fossil energy budget which we are addressing here today.

This recommendation essentially continues the same programs funded by Congress last year through appropriations of $63 million. Essential to this recommendation is the fact that the gas industry through GRI is planning to commit $62 million in 1989 in near-term research in these same program areas. Essentially, the gas industry is requesting DOE fund gas-related research in a longer term in its fossil energy program at a budget level equal to the amount of near-term research, the gas industry's funding through GRI.

GRI is an independent, not-for-profit research organization. While we are not a DOE contractor, we do coordinate and co-fund much of our work with DOE. Therefore, national energy policy reflected through the DOE budget does have a major impact on the gas industry's individual R&D efforts.

During most of the 1980's, this Administration has not counted gas as a key element in planning to meet the Nation's energy demand. However, DOE officials have made policy statements during the past 18 months that indicated they are beginning to recognize the major role gas can play in the Nation's energy future

DOE recently announced a major new study, as Mr. Baly referred to a while ago, to perform a comprehensive assessment of U.S. natural gas reserve potential. In announcing the study, Secretary Herrington stated our growing dependence on imported oil is an Achilles' heel. He further stated this is an opportune time to reassess the role natural gas can play in displacing imported oil, and indicated the study would look at displacing as much as 1 million barrels of oil per day.

The Energy Security Study released just last March by DOE concluded that U.S. oil imports will probably increase substantially by 1995. The study also concluded that natural gas is the fuel that is the most readily substituted for oil and natural gas is an abundant domestic resource. The study said that targeted R&D and fossil fuels including unconventional gas, is one critical step that the U.S. could take to reduce its dependence on imported oil.

These policy statements are all very encouraging. However, when the DOE Fossil Energy budget is examined in detail it is not consistent with any of the above policy statements. The budget request for all of Fossil Energy is $168 million, only 1 percent of the total DOE budget request and a reduction of 49 percent from the money Congress appropriated just two months ago. The requested gas-related research budget is just $17 million in fossil energy, less than 25 percent of the fiscal year 1988 appropriated funds.

In unconventional gas, which the Energy Security Study specifically targeted as an opportunity, the DOE request is $1.7 million, a reduction of 83 percent and a sharp contrast to the $10 million appropriated by Congress in December. Additionally, no specific funds are requested for geosciences research. So while the Administration talks about the increasing importance and strategic role of gas in reducing our dependence on oil, the budget does not support the policy. While it is unreasonable to assume that the U.S. can become completely energy independent anytime in the near future, several options are available to ease the oil import level.

One obvious solution is to substitute natural gas where technically possible in areas that are currently adding to the oil import. This requires a continued joint effort to an industry in the Federal Government. GRI and the gas industry are recommending $67 million for DOE gas research continuing programs funded by Congress over the past three years, to be matched by $62 million of funds from GRI.

Specific areas that we are interested in, Mr. Chairman, are unconventional natural gas where we are proposing $20 million to the DOE budget. GRI is funding $30 million and we anticipate about $14 million of co-funding from our industrial partners in this area.

We think DOE should fund $6 million of work in the tight sands in the West; $6 million in the Eastern Devonian shales; and $3 million in the secondary gas recovery program that we are entering into with DOE and the Bureau of Economic Geology at the University of Texas this month. We hope to negotiate this program with DOE. To continue the program as planned requires $3 million in the 1989 DOE budget. GRI and our industrial partners will put up about 60 percent of the total funds.

The other area that we think is important to continue and provide additional funds is geosciences. The gas industry is especially appreciative to this Subcommittee and to you, Mr. Chapman, for the interest and the initiative that you took last year to get this geosciences initiative started.

We think there should be a total appropriation of $20 million of which $10 million should be for gas related research.

Finally, in the area of fuel cells, Mr. Chairman, we believe that DOE should continue to fund the advanced fuel cell technologies in solid oxide and molten carbonate at a level of about $10 million each, and a $2.5 million base technology program in fuel cells.

Essentially, the gas industry is challenging DOE to fund long-term research at the same level that the gas industry is funding through GRI of near term research in these program areas. Thank you very much, Mr. Chairman.

[The prepared statement of Mr. Webb follows:]

STATEMENT OF DAVID O. WEBB, SENIOR VICE PRESIDENT POLICY AND REGULATORY AFFAIRS, GAS RESEARCH INSTITUTE BEFORE THE SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT HOUSE SCIENCE, SPACE, AND TECHNOLOGY COMMITTEE U.S. HOUSE OF REPRESENTATIVES

MARCH 3, 1988

INTRODUCTION

Good morning, Madam Chairman and members of the Subcommittee. I appreciate the opportunity to appear before you today to present Gas Research Institute's (GRI) FY 1989 budget recommendations for gas-related research in the Department of Energy's (DOE) Fossil Energy program. The recommendations reflect the minimum funding required to continue a viable gas research program in DOE. In developing these recommendations, GRI balanced the conflicting priorities--the need to reduce federal expenditures and the need to maintain essential research to reduce the nation's vulnerability to imported oil. In this light, GRI and the gas industry have agreed upon a minimum recommendation of $114.35 million for gas-related research in DOE. Of this recommendation, $67 million is for fossil energy R&D, which I will discuss in today's testimony. This recommendation essentially continues the same programs funded in the $63 million appropriated by Congress for FY 1988. Central to this recommendation is that GRI is planning to commit $62 million to near-term research in the same programs--gas supply, fuel cells, coal gasification, and gas for environmental emissions control--in 1989. Essentially, the gas industry is requesting DOE fund longer-term gas-related research in its fossil energy program equal to the amount of near-term research the gas industry funds through GRI.

GRI is an independent, not-for-profit scientific research organization that plans, manages, and finances a cooperative R&D program for the benefit of its 255 members and their customers. The R&D program is implemented through over 500 contracts with research organizations, engineering firms, universities, energy companies, and manufacturers.

National energy R&D policy reflected in DOE's budget is a major factor influencing the GRI program since GRI cofunds and coordinates many of its research projects with DOE. Therefore, even though GRI is not a government contractor, congressional action on the proposed DOE FY 1989 budget has a direct impact on the gas industry's R&D program.

DOE ENERGY POLICY STATEMENTS VS. BUDGET REALITY

During most of the 1980s, the Administration did not count gas as a key element in meeting the nation's future energy demand. However, DOE officials have made policy statements during the past 18 months that indicate they are beginning to recognize the major role gas could play in the nation's future.

DOE has recently announced a major new study to perform a comprehensive assessment of U.S. natural gas reserve potential. In announcing the study, Secretary Herrington stated "our growing dependence on imported oil is an Achilles heel." He further stated "this is an opportune time to reassess the role natural gas can play in displacing imported oil." The Department study will also assess the potential of natural gas to displace as much as 1 million barrels of oil per day.

The DOE Energy Security Study released last March concluded U.S. oil imports will probably increase substantially by 1995 ranging from 8 to 10 million barrels per day--about one-half or more of total projected U.S. oil consumption. The study also concluded that natural gas is the fuel that is most readily substitutable for oil, and natural gas is an abundant domestic resource. DOE projected that if unconventional resource are included, the nation's supplies of natural gas may support 200 years of U.S. consumption at current rates. The study indicates targeted R&D in fossil fuels including unconventional gas is one critical step to reducing U.S. dependence on imported oil.

When the DOE budget books were submitted to Congress two weeks ago, they indicated that one of the two overall strategic objectives for Fossil Energy is ". . . increase the effective resource base for premium liquid and gaseous fuels through enhanced resource recovery . . ." A primary objective of the Fossil Energy gas program is to "foster geoscience research and development of unconventional and novel natural gas resources which can add to the supplies of natural gas from conventional sources."

This is all very encouraging; however, when the DOE Fossil Energy budget request is examined it is not consistent with any of the above policy. The budget request for all Fossil Energy projects is $168 million, a reduction of 49 percent from the $327 million appropriated by Congress just two months ago. In the unconventional gas area, DOE requested only $1.7 million, a reduction of 83 percent and a sharp contrast to FY 1988 appropriations of $10.9 million. No specific funds are requested for gas-related geoscience research. While the Administration talks about the increasing importance and strategic role of gas in reducing the U.S. dependence on oil imports, the budget does not support the policy.

The GRI budget recommendations I am presenting here today restore funding to critical technology-based fossil energy programs in unconventional gas, geosciences, coal conversion technologies, and fuel cells consistent with DOE's public policy statements. We must have a viable government/industry joint R&D effort if gas is to fulfill its potential.

U.S. ENERGY OUTLOOK

The necessity of continuing a viable fossil energy R&D policy to include critical gas-related research projects becomes evident when we examine where the U.S. is projected to get most of its energy supplies over the next 25 years. DOE's projections in the December 1985 National Energy Policy Plan indicate that in the year 2000, the U.S. will meet over 80 percent of its energy needs with oil, gas, and coal. GRI's projections indicate that in the year 2010, the U.S. will still get 75 percent of its energy from fossil resources. (See exhibit 1) However, DOE has allocated only approximately 1 percent of its total FY 1989 budget to fossil energy research. This is an obvious imbalance and does not acknowledge the critical role fossil fuels will play in meeting the U.S. energy demand for the next 20 to 30 years.

Exhibit 1
U.S. Primary Energy Consumption
(Quads)

	Actual			
	1986	1990	2000	2010
Petroleum	32.3	32.0	35.3	38.3
Gas	16.5	17.1	18.5	18.9
(Total Gas Fuels)*	(16.6)	(17.3)	(18.8)	(19.3)
Coal	17.3	17.4	20.2	25.4
Nuclear	4.5	6.4	6.4	6.1
Renewables	6.4	6.8	8.3	9.7
TOTAL	77.0	79.7	88.7	98.4

1987 GRI Baseline Projection

*Total gas fuels includes 0.2, 0.3, and 0.4 quad of "other" gas, primarily SNG from petroleum and miscellaneous gases, and high-Btu coal gas, in 1990, 2000, and 2010 respectively.

U.S. Oil Consumption/Import Outlook

A U.S. energy policy that essentially ignores fossil fuels R&D and the role abundant gas resources could play in meeting future energy demands hastens the day oil imports exceed 50 percent of consumption. In 1987 oil imports were responsible for approximately 25 percent of the record U.S. trade deficit. To continue to cut critical fossil fuels and gas research at a time when the domestic oil and gas production industry is nearly devastated is not sound national policy.

The American Petroleum Institute recently released a report indicating the number of wells drilled in search of oil and gas in 1987 declined more than 10 percent from the 1986 level of 35,000 wells and more than 60 percent from the exploration peak of 91,000 wells in 1981. U.S. production plummeted by 400,000 barrels a day during 1987 to a total of 8.28 million barrels per day. Meanwhile, U.S. consumption increased by 300,000 barrels per day, or more than 5 percent. The reduced production and increased consumption are forcing the U.S. into an even greater dependence on foreign oil, and most of the sources of foreign oil are susceptible to disruption. Imports now account for approximately 40 percent of U.S. consumption. This is the highest level since the end of the 1970s.

Petroleum consumption is projected by GRI to grow at approximately 2-3 percent per year, the same rate as total primary energy consumption, for the next 25 years. Meanwhile, domestic petroleum production including natural gas liquids is projected to decline from 10.3 million barrels per day in 1986 to only 6 million barrels per day in 2010. Without a significant federal and private-sector research program to extract more oil from known reservoirs and to develop our other domestic resources, net oil imports could reach 12.5 million barrels per day by 2010.

While it is unreasonable to assume that the U.S. can become completely energy independent anytime in the near or mid future, several options are available to ease the high import level. One obvious option is to substitute natural gas where technically possible in areas that are currently adding to the oil imports. These areas include introducing natural gas vehicles in the transportation sector, gas-fired combined-cycle power generation, cogeneration, gas use in industrial steam applications, and many commercial- and residential-size heating and cooling applications, to name a few. However, this cannot happen without advances in the technology base and an expanded research program in unconventional gas. If gas is to fulfill its potential in the U.S. energy mix, a viable federal research program must be maintained and funded. The DOE budget as submitted does not provide for this essential research.

U.S. Natural Gas Resource Base

The U.S. natural gas resource base is huge. The natural gas resource base was verified as recently as last March in the DOE Energy Security Study. With advances in technology, gas will maintain an important role in a highly competitive future U.S. energy mix well into the next century (See Exhibit 2). This future depends on continuing funding for a viable federal/gas industry research program to produce the technology base necessary to develop plentiful cost-competitive gas supplies and more efficient appliances, equipment, and gas processes. Developing this technology base requires a 10- to 15-year lead time. Maintaining a viable federal research program is critical since by the year 2010 approximately 25 percent of U.S. gas supplies will be dependent on new initiatives that require advanced technology.

Exhibit 2
Gas Supplies
(Quads)

Current Practice	1985	1990	2000	2010
Domestic Production	16.6	16.3	14.3	9.3
Canadian Imports	0.8	0.9	1.4	1.1
LNG Imports	0.0*	0.1	0.3	0.8
Supplemental Sources	0.0	0.2	0.3	0.3
	17.4	17.5	16.3	11.5
New Initiatives				
Lower-48 Adv. Tech.	0.0	0.3	2.6	5.4
Alaskan Pipeline	0.0	0.0	0.0	1.2
Canadian Frontier	0.0	0.0	0.5	0.7
Other Imports	0.0	0.0	0.0	1.0
Synthetics	0.0	0.0	0.0	0.1
Total Supply	17.4	17.8	19.4	19.9

*Less than 0.05 quad

PROPOSED JOINT DOE/GAS INDUSTRY GAS RESEARCH PROGRAM

A continued joint effort between industry and the federal government is needed to ensure a stable, reliable energy mix for this nation's security. To maintain a joint effort, GRI makes the following recommendations for DOE's budget. In many cases, the projects covered by these recommendations are being coordinated or cofunded with gas industry funding. These recommendations concentrate the DOE funds in longer-term technologies such as coal gasification, advanced fuel cells, and geosciences while GRI focuses on near-term applications in unconventional natural gas, gas-enhanced emissions control, and materials and components.

Exhibit 3
Gas-Related Research Recommendations
for DOE FY 1989 Fossil Energy Program
($ Millions)

	DOE Budget Recommendations FY 1989	GRI Planned Budget 1989
ARTD (Gas-Related)	$ 6.00	$ 11.20
Fuel Cells (Gas-Related)	22.70	3.80
Coal Gasification	16.75	1.90
Unconventional Natural Gas	10.00	30.40
Gas-Related Geosciences	10.00	2.70
Gas-Enhanced Emission Control	N/A	6.50
Basic Research	N/A	5.00
Liquid Spill Test Facility	1.50	0.50
	$ 66.95	$ 62.00

The above GRI totals reflect only a partial picture of the gas industry's R&D effort. GRI's total 1989 R&D budget is planned at $146.7 million. The R&D program includes supply, end use, gas operations, and crosscutting research (see Exhibit 4).

Exhibit 4
GRI R&D Program Budgets

	1988		1989*	
	Budget ($M)	Percent	Budget ($M)	Percent
Supply Options	37.3	25.8	40.200	27.4
End Use	82.2	56.8	80.505	54.9
Gas Operations	18.7	12.9	19.975	13.6
Crosscutting Research	6.5	4.5	6.020	4.1
	144.7	100%	146.700	100%

*Preliminary estimate--not yet FERC-approved

GRI's R&D program helps to ensure, both now and in the future, the widest use of natural gas that is consistent with a least-cost energy strategy. Major emphasis is placed on development of technologies that have the potential to increase the value of natural gas in existing applications and that are critical to new, high-form-value applications in which economic or other advantages can be identified. More specifically, GRI's program is designed to:

1. Decrease the cost of producing and delivering gas while increasing its value to end users,

2. Enhance the role of gas in providing least-cost energy services while recognizing the importance of maintaining and increasing the superior quality, convenience, safety, and reliability of gas energy service at competitive prices,

3. Facilitate the transfer of new technology and technical and scientific information to the gas industry and its customers, and

4. Stimulate innovation in gas-related technologies through a mission-oriented basic research program.

In contrast to the DOE proposal to drastically reduce funding for long-term gas-related research, the gas industry's response to federal R&D policy directing industry to fund more of its own near-term R&D has been very impressive. While DOE has proposed only about $17 million for FY 1989 gas-related research in the fossil program--less than 25 percent of FY 1988 appropriated funds--GRI will fund approximately $62 million of near-term activities in these research areas.

An effective joint research effort by the government and industry requires a viable long-term gas research program in DOE. This is best illustrated by a General Accounting Office report dated February 11, 1987. It concludes that "private industry has not picked up much of the energy R&D curtailed by DOE." This has significantly delayed U.S. technology development.

To establish this effort, GRI is recommending $67 million for gas-related research in DOE's Fossil Energy program to fund the long-term technology base. (See Exhibit 5.) In the past three years, Congress has recognized the need for a long-term DOE gas-related program to supplement the near-term GRI program and has appropriated approximately $65 million each year for these DOE programs. The gas industry is seeking a continuation of this trend in FY 1989. Maintaining funding for ongoing DOE programs is critical if the U.S. is to develop the technology required to economically extract our resources and reduce the dependence on imported oil.

Exhibit 5
Recommended DOE Gas-Related Budget for FY 1989
For Fossil R&D
($ Millions)

	FY 1986 Approp.	FY 1987 Approp.	FY 1988 Approp.	FY 1989 Budget Recommend's.
ARTD	$10.4	$ 8.6	$ 6.0	$ 6.0
Fuel Cells (Gas-Related)	19.4	14.7	20.5	22.7
Surface Coal Gasification	41.3	24.6	21.4	15.0
Unconventional Natural Gas	8.5	8.1	10.9*	20.0*
Underground Coal Gasification (Technology Base)	4.1	2.4	2.8	1.8
Liquid Spill Test Facility	1.0	2.0	1.0	1.5
Subtotal	$84.7	$60.4	$62.6	$67.0
Gas-Enhanced Flue-Gas Cleanup (Clean Coal Technology Fund)	N/A	15.0	0.0	0.0
Total	$84.7	$75.4	$62.6	$67.0

*Includes geoscience activities.

DOE FY 1989 GAS-RELATED RESEARCH PROGRAM RECOMMENDATIONS

While the Administration continues to request budget levels far below what is necessary to conduct critical R&D in fossil, conservation, and renewable energy, Congress has consistently increased these budget areas to provide a consistent funding level for ongoing research. To attract industrial funding partners in this research effort, it is necessary to maintain this continuity in funding and support for these ongoing programs. In its recommendations for gas-related research, GRI and the gas industry have for the most part, requested funds for maintenance of ongoing programs that Congress has supported in the past. Following is a recommendation for specific programs of particular interest to GRI.

Unconventional Natural Gas

Western Tight Sands	FY 1987 Appropriation	FY 1988 Appropriation	FY 1989 Recommendation
	$5.4 million	$3.3 million	$6.0 million

Significant amounts of potentially recoverable natural gas exist in low-permeability sandstone formations located in sedimentary basins throughout the U.S. Current information indicates that the total amount of economically recoverable gas from tight sands could be in excess of 500 Tcf. However, a combination of technical limitations and economic constraints prevent the widespread commercial exploitation of these resources. It is estimated that the development of advanced technologies and practices applicable to tight gas sands could provide an additional 200 Tcf of cost-competitive gas over what is recoverable with the present state-of-the-art technology.

Gas-bearing tight sands occur in the form of blanket-type and lenticular formations. In both types the effects of a variety of interdependent parameters are still unknown, and, consequently, the gas recovery rate and active reservoir life for a given field remain uncertain. The following specific technological issues need to be addressed to permit low-cost exploitation of the full potential of the tight sands resource base:

1. Determine the relationship between geologic and engineering parameters,
2. Further characterize tight sands gas reservoirs and improve resource estimates,
3. Identify the parameters critical to formation evaluation and gas production,
4. Understand more clearly the mechanisms of hydraulic fracture propagation and control,
5. Diagnose fracture shape and downhole conditions using surface parameters,
6. Provide real-time fracture treatment design changes, and
7. Apply advanced technologies to presently noncommercial areas.

Geotechnical and economic analyses have demonstrated that blanket-type formations are more amenable to production in the near term because the geologic environments in which they exist are less complex than the environments associated with lenticular formations. Therefore, GRI has concentrated its efforts in the near-term aspects of blanket-type formations such as resource characterization, formation evaluation, fracture diagnostics, and real-time analysis development. In 1989 GRI plans four staged field experiments to validate technologies developed in this project area. GRI's 1989 budget for tight gas sands is $10.6 million. In addition, GRI anticipates industrial partners will contribute another $7.5 million. GRI recommends DOE commit $6 million for longer-term research in the lenticular formations.

Eastern Devonian Shales	FY 1987 Appropriation	FY 1988 Appropriation	FY 1989 Recommendation
	$0.455 million	$2.3 million	$6.0 million

The large eastern Devonian gas shales resource base underlies approximately 175,000 square miles of the eastern United States. Current information indicates the gas-in-place is approximately 2000 Tcf; however, there is a great deal of uncertainty regarding how much of that resource may be recoverable. There is approximately 120 Tcf of gas-in-place in a drillable area of 22,000 square miles in the heart of the Appalachian Basin, and projections indicate that up to 50 Tcf of this gas may be technically recoverable.

In general, two major factors constrain present-day exploitation of this resource: (1) the inability to predict with confidence the gas production rates that will be obtained in wells drilled outside of historical production areas, and (2) the inconsistent response of formations to currently employed stimulation practices. Because most of the producers in the Appalachian Basin are small independents, they cannot afford to conduct the comprehensive R&D required to understand and solve these problems. A federal program is required.

Barriers to economic production of natural gas from Devonian shales include:

1. Inadequate understanding of factors that control the flow of gas from Devonian shale formations to the wellbore,
2. Lack of effective exploration rationales to identify geographic areas and stratigraphic zones with highest production potential.
3. The need for improved diagnostic methods to assess the potential of productive zones.
4. Inadequate understanding of shale gas reservoir dynamics, and
5. The lack of generally effective stimulation techniques.

Economic exploitation of the full resources hinges on development of improved techniques and technologies for overcoming these limiting factors.

GRI's program in eastern Devonian shales includes reservoir evaluation, recovery enhancement methods, geologic production controls, and development of a resource well information data base.

GRI's 1989 budget for eastern Devonian shales is $4.8 million with an additional $3.6 million in industrial funding expected. The gas industry recommends a total of $6 million for DOE research of eastern Devonian shales.

Secondary Gas Recovery	FY 1987 Appropriation	FY 1988 Appropriation	FY 1989 Recommendation
	NA	$2.5 million	$3.0 million

A significant quantity of natural gas that requires minimal exploration and is in close proximity to gathering systems and pipelines is known to exist in currently producing and abandoned wells and fields. These potential reserve additions consist of gas-in-place that was not identifiable or economically producible with state-of-the-art primary production practices and new pool discoveries in existing fields that cannot be exploited with present infill drilling strategies. The total technically recoverable resource from these sources is estimated at 600 Tcf. Of this, approximately 70 Tcf is thought to be economically recoverable with the development of advanced technologies and practices. Equally important is the projection that by using advanced technologies and practices, these sources could provide 3-4 Tcf of gas at $2/Mcf by the early 1990s since the initial exploration has been accomplished already. Developing the knowledge and the technology to recover these reserves will allow the demand for low-cost gas to be met in a timely manner when the current surplus is absorbed over the next two or three years.

To illustrate the potential, consider that the recovery of gas-in-place has traditionally been estimated to be in the 80-90 percent range; however, recent data have indicated these estimated recovery efficiencies are often too high. For example, recovery efficiencies for the prolific water-drive gas reservoirs along the Texas and Louisiana Gulf Coast are now estimated to be 50 percent or less, and recent submittals for infill drilling in the Hugoton field implied a recovery factor of about 55 percent. These poor recovery efficiencies result from the encroachment of water and subsequent trapping of gas in water-drive reservoirs and from reservoir heterogeneities in more conventional reservoirs. Improved drilling, completion, and production techniques would have an immediate impact on gas recovery from these reservoirs. Estimated additional recovery from existing fields in just three states (Texas, Louisiana, and Kansas) range up to 75 Tcf.

One way to more efficiently produce gas from the Gulf Coast water-drive reservoirs is to use advanced methods for recovering the trapped gas. These advanced methods are based on the coproduction theory which suggests that a major portion of the trapped gas can be remobilized and flow to the production well if water is produced from one or more wells in a water-drive reservoir at such a high rate that the reservoir pressure is significantly reduced. If the reservoir is geopressured (above hydrostatic pressure, or greater than 0.465 pounds per square inch per foot of depth), the water will flow from the production well by itself. If the reservoir is hydropressured or underpressured, the water will not flow freely to the surface, and artificial lift techniques will be required. Specific technical issues that need to be addressed include: (1) developing improved methods to mitigate and control scaling/corrosion problems caused by produced brines, (2) validating the theory of coproduction in the field, (3) solving the practical problems associated with production equipment and gas processing, (4) developing and validating numerical models, expanding simulation capabilities to permit accurate prediction of expected reservoir performance, and (5) conducting field-based research to test and confirm production and completion strategies.

In addition to the coproduction of gas and water from water-drive reservoirs, a substantial quantity of gas exists in the form of bypassed gas zones in existing wells and in undiscovered reservoir compartments, such as stratigraphic traps, in developed fields. Bypassed gas is difficult to detect using commercially available formation evaluation techniques because the techniques are primarily geared toward use in uncased (open-hole) wellbores. Once casing is set, reservoir properties are masked by the casing and cement, and additional completion possibilities must be evaluated from previously acquired open-hole data and/or limited data from existing cased-hole tools. These data are often either insufficient or inaccurate. Development of logging techniques for cased holes is needed to identify and characterize these bypassed zones.

Undiscovered reservoir compartments in developed fields are gas zones that are not in contact with the drainage pattern of the field due to reservoir heterogeneities. In gas fields that are developed on 640- to 320-acre well spacing, which is typical, reservoir heterogeneities are an important determinant of recovery factors. Without an understanding of the internal barriers to effective reservoir drainage, a significant part of the gas resource may remain untapped. In many conventional reservoirs, it is estimated that 30-50 percent of the gas-in-place remains unrecovered under prevailing development patterns. Currently, there is an evolving emphasis in infill drilling to improve recovery; however, research is needed to permit application of sound geologic principles rather than empirical geometric "rules of thumb" to guide well placement.

Specific technological issues which need to be addressed include:

1. Improving the understanding of geologic environments and characteristics of gas fields to allow for resource identification and estimates,

2. Providing a methodology for cased-hole formation evaluation, and

3. Developing in-field reexploration rationales based on an understanding of heterogeneities.

Currently, GRI's program addresses resource characterization, coproduction of trapped gas and water, and brine treatment and control. A new joint initiative with DOE will be undertaken in 1988 to conduct field experiments on identifying and producing bypassed gas in undiscovered reservoirs in known fields. The field experiments will be conducted as a joint R&D venture; GRI and industry will contribute over 50 percent of the costs. DOE funding of $3 million is required in 1989 to continue this joint program as scheduled.

GRI's 1989 budget for secondary gas recovery is $4.2 million with an additional $2.5 million expected from industry.

Geoscience Recommendation	FY 1987 Appropriation	FY 1988 Appropriation	FY 1989 Recommendation
	N/A	$6.0 million	$10.0 million

GRI believes that in addition to increasing traditional energy R&D dollars, DOE needs to reevaluate its basic energy research goals and to address a hydrocarbon geoscience research program. GRI is pleased with the results of the FY 1988 budget recommendation in the area of geosciences to develop a comprehensive geoscience and enhanced recovery research and development program and to establish a field office in Matairie, Louisiana, for gas and light-oil research and development programs. The congressional emphasis on geoscience research is a step in the right direction. However, now more needs to be done. For the next 25 years, GRI estimates that oil and gas will provide over 50 percent of U.S. energy needs. Almost all the domestic oil and gas production by 2010 probably will come from fields and reservoirs not yet discovered and/or enhanced recovery technologies to produce the nearly two-thirds of the oil currently left in the ground. Whatever is not produced from these domestic discoveries will have to be satisfied by imported oil, primarily from OPEC nations.

Despite this acknowledged demand for oil and gas, the DOE budget allocates no specific funds to research in these geoscience program areas. Funds must be provided to follow up on last year's congressional initiative.

To initiate a geoscience program, GRI recommends DOE commit a total of $20 million with $10 million in FY 1989 for geoscience-type gas research. This $10 million funding could be directed to programs such as R&D in reservoir heterogeneity and subtle traps as well as advanced oil and gas geoscience technology.

GRI recommends a geoscience program in DOE's Fossil Energy program that recognizes:

1. The continued decline in private-sector oil and gas R&D in general and in fundamental geoscience research in particular has increased the urgency for a viable federal role in oil and gas research to maintain domestic production to reduce dependency on imported oil.
2. The DOE creation of an Office of Geoscience Research in Fossil Energy and a Hydrocarbon Geoscience Research Coordinating Committee must be adequately funded so they can implement a research program plan.
3. The level of funding is grossly inadequate to meet existing federal "mortgages" in oil and gas research and does not provide for any geoscience work.
4. There is a need to establish a viable state/federal/private consortium to help coordinate and conduct critically needed field tests in hydrocarbon geoscience research.

Therefore, GRI recommends gas-related hydrocarbon geoscience R&D receive at least $10 million in FY 1989. Furthermore, this funding should be established as a separate line item in Fossil Energy--"Hydrocarbon Geoscience R&D." Also, Congress should require DOE to submit an annual report from the Hydrocarbon Geoscience Research Coordinating Committee which details all the oil- and gas-related geoscience research conducted in DOE. The report should identify how the basic science research knowledge could be applied to other geoscience areas to increase technology transfer to industry.

	FY 1987 Appropriation	FY 1988 Appropriation	FY 1989 Recommendation
Surface Coal Gasification	$24.655 million	$21.4 million	$15.0 million

One of the most promising, abundant long-term sources of gas supply is the conversion of coal to gas. Even in the near term, the use of gas-fired combined cycle equipment with the future capability to utilize gas produced from coal to fuel the system offers the most promising solution to using the nation's coal to generate electricity in an environmentally acceptable manner. To realize this potential, it is necessary to validate the essential economic and detailed design data of the current state-of-the-art coal gasification process by the mid-1990s.

GRI has been supporting a study to evaluate the effect of gasifier pressure on the operation and performance of oxygen-blown ash-agglomerating fluid-bed gasifiers. This research, which IGT is conducting, is worthwhile and interests a wide audience. Finishing this research will require support of approximately $1 million per year from DOE for about two years. Research is also needed on a novel contamination control system that could contribute to an advanced gasification process. IGT is conducting this work which will require $2.5 million in FY 1989.

	FY 1987 Appropriation	FY 1988 Appropriation	FY 1989 Recommendation
Underground Coal Gasification	$2.37 million	$2.825 million	$1.75 million

Underground coal gasification offers a method for recovering coal resources without the need for mining by gasifying the coal in-place underground. Oxygen in conjunction with steam is injected into an underground coal bed to drive and control the gasification reactions. Underground coal gasification may be able to tap those vast coal deposits that would not normally be economically recoverable using existing or anticipated strip- or deep-mining methods. Underground coal gasification is, therefore, applicable to a different coal resource base than surface gasification. In comparison with present-day surface gasification processes, underground technology offers a projected 15-25 percent cost savings as well as possible environmental and safety advantages.

At the present time, underground coal gasification must be classified as a high-risk, advanced technology, but one with very high payoff potential. This high payoff would be due, at least in part, to the very large potential resource base to which this technology can apply. DOE has estimated that, of the current 6.4 trillion tons of domestic coal resources, only about 0.5 trillion tons are currently economically recoverable using existing surface- and deep-mining techniques. Underground coal gasification could potentially use about 1.8 trillion tons of coal and produce more that 1000 Tcf of substitute natural gas, even if only 10 percent of U.S. coal resources are suitable for gasification.

Major problems confronting successful development of underground coal gasification technology include the verification of low-cost, reliable, and reproducible methods for providing a pathway between injection and production wells (linking); control of the combustion front and gas quality; prediction and mitigation of subsidence potential and other environmental impacts; and uncertainty over how to achieve optimum utilization of the coal resource.

Since 1979, GRI has worked with DOE in efforts to prove the economic feasibility of in situ gasification. Prior to that, air-blown underground tests conducted by DOE at Hoe Creek, and Hanna, Wyoming, demonstrated basic technical feasibility and environmental acceptability even as the need for improvements in controlling the gasification process was identified. Experiments conducted at Hoe Creek No. 3 by Lawrence Livermore National Laboratory (LLNL) and supported by GRI demonstrated that directionally drilled wells can be successfully completed, that oxygen-blown burns can be controlled, and that the instrumentation and data acquisition systems necessary for reliable in situ gasification can be developed. Although some subsidence was recorded following the burn, the results of Hoe Creek No. 3 were a positive sign that a future exists for underground coal gasification.

During 1980-1981, the Joint DOE/GRI In Situ Coal Gasification Program began the development of a new site at Centralia, Washington, to conduct a deep (300 to 400 feet) flat-bed test using the directionally drilled linkage technology developed at Hoe Creek No. 3. An outcrop of the subbituminous coal seam selected for the deep test permitted smaller-scale tests to determine gasification characteristics of the seam. Five oxygen-blown block tests (3- to 5-day experiments) conducted in the outcrop in 1981-1982 verified the suitability of the coal for in situ gasification.

The final block test also established the feasibility in the field of the new controlled-retracting-injection-point (CRIP) concept developed by LLNL. This concept provides the capability of reducing cavity and roof interactions that can decrease gas quality during the burn by controlled relocation of the burn cavity within the coal seam when cavity/roof interactions begin. The first large-scale test of the CRIP technology (a 30-day test at Centralia under DOE and gas industry sponsorship) was successfully completed in 1983.

GRI, DOE, Amoco, Union Pacific Industries, Stearns-Roger (Division of United Engineers and Contractors), Energy International, LLNL, and Western Research Institute recently concluded a 100-day burn at Rocky Mountain I project in Hanna, Wyoming. Field operations and initiation of a burn began in mid-November. To date, the experiment is considered the most successful underground coal gasification project in the U.S.

Although all these tests have been successfully completed, there continues to be a need to conduct R&D on the applicability and reliability of this approach in producing gas from deep seams as well as near-surface seams from steeply-dipping beds and from bituminous as well as subbituminous coal. In addition, continued technical and economic analysis is required to determine the impact on gas cost of variations in site parameters such as well spacing, environmental control requirements, coal seam depth, tilt and thickness, product-gas quality, linking technique, and facility size.

Continued DOE support is needed to do post-burn coring and generic environmental work at the Rocky Mountain I site. In addition, DOE should consider conducting tests on eastern coals.

GRI's 1988 budget for underground coal gasification is $800,000 with an additional $375,000 expected from industrial partners. The recommendation for DOE is $1.75 million.

	FY 1987 Appropriation	FY 1988 Appropriation	FY 1989 Recommendation
Fuel Cells	$14.9 million	$20.45 million	$22.7 million

A fuel cell is a cogeneration power plant that uses natural gas in an electrochemical process to produce electricity, heat, and water. Installed onsite at a multifamily residential, commercial, or light-industrial building, the fuel cell power plant can supply all or part of the electrical and heating requirements of the building. This is accomplished using one fuel source, natural gas, and with very high overall energy efficiencies, good reliability, low noise, and virtually no pollutants. Use of an onsite fuel cell power plant in sizes from tens to hundreds of kilowatts of electrical output can provide the commercial gas ratepayer with lower total energy bills while also providing the gas industry with new market opportunities for providing cost-effective onsite energy service to its customers and achieving the economics of operation associated with load-leveling and high-utilization profiles for pipelines.

Two types of advanced fuel cells appear promising: the solid oxide fuel cell and the molten carbonate fuel cell. The solid oxide fuel cell appears particularly promising because of its ability to utilize methane directly without extensive reformer equipment, and its potential for development as a simpler and possibly less expensive system. However, major development efforts are required before the solid oxide fuel cell system can be commercialized. Fundamental research is needed on cell fabrication technology, electrical interconnect, thermal cycling, internal electrical losses, scale-up, system component integration, direct methane use, and heat recovery. These issues must be resolved before detailed solid oxide fuel cell system development can be undertaken.

Research on molten carbonate fuel cell technology has been conducted for use in central-station electric generation. Although molten carbonate systems are further developed than solid oxide systems, major development efforts are needed in the cell stack area before the molten carbonate system concept can be commercialized. These development efforts include activities that have long development times and represent major technological hurdles: cathode solubility, electrolyte loss, corrosion, and thermal cycling.

In the area of phosphoric acid fuel cells, the federal funding requirement for the onsite program is complete. However, it is recommended that DOE recognize a need to maintain a generic program for the phosphoric acid fuel cell for activities such as advanced electrolytes.

GRI is currently pursuing work in integrated systems development (phosphoric acid), subsystem technology improvements (phosphoric acid), and technology base for advanced concepts (solid oxide).

GRI's 1988 budget for fuel cell activity totals $4.5 million with an additional $3 million from industrial partners. The gas industry recommends a DOE budget of $22.7 million for molten carbonate and solid oxide fuel cells and a generic program in phosphoric acid fuel cells.

SUMMARY

GRI recommends the Department of Energy continue to fund a viable, consistent gas-related program in Fossil Energy that adequately addresses the long-term needs of this nation's energy supply. A total of $67 million would continue the programs Congress has already approved in past years. We believe this budget recommendation is consistent with the realities resulting from the large budget deficit since it is approximately the same as the FY 1988 appropriation for these same programs. It should be noted that the gas industry is funding near-term research in these program areas with a GRI R&D budget of approximately $62 million. These central themes of funding adequate long-term gas research in DOE while GRI funds near-term research and of strengthening the oil- and gas-related geosciences program are sound national energy policies that Congress should implement.

Gas Industry Recommendation
FY 1989 Gas-Related DOE Budget
($ millions)

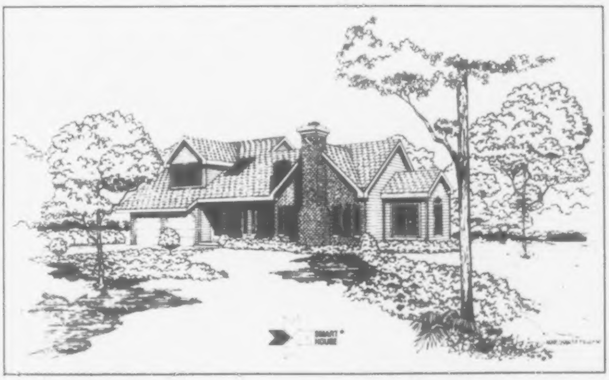
ARTD (Gas-Related)	$ 6.00
Fuel Cells (Gas-Related)	22.70
Surface Coal Gasification	15.00
Underground Coal Gasification	1.75
Unconventional Natural Gas	20.00*
Liquid Spill Test Facility	1.50
TOTAL	$ 66.95

*Includes geoscience activities.

GAS RESEARCH INSTITUTE

An Overview

January 1988



Innovative residential gas technologies and equipment will be evaluated in a GRI-funded gas Laboratory Smart House to be built at the National Association of Homebuilders (NAHB) Research Home Park in Maryland. The first fully operational "smart house," the home will feature advanced wiring, energy monitoring and control systems, innovative gas piping systems, and zoned gas heating. Refinement of these gas and electronic technologies will ensure that gas continues to remain competitive in a major share of the new residential construction market in the future.

GRI

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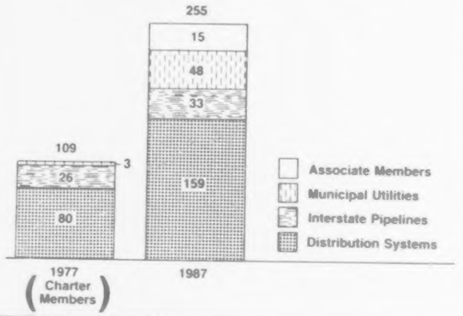
THE GAS INDUSTRY'S RESEARCH MANAGEMENT ORGANIZATION

- A Unique Approach to Cooperative Energy R&D
- R&D Investment Broker
- Contracts to Industry, Government, University Researchers
- Products in the Market

Gas Research Institute (GRI) is a not-for-profit membership organization of natural gas pipeline and distribution companies. GRI plans, manages, and develops financing for a research and development (R&D) program designed to advance gas supply, transport, storage, and end-use technologies and to conduct related basic research. GRI conducts no R&D itself, but the GRI program includes almost 500 active research contracts with leading performers of R&D. GRI's research has a market focus in recognition that results must leave the laboratory and enter the market as successful products or processes to provide benefits to the ratepayers and gas industry.

GRI MEMBERSHIP GROWTH



GRI is a voluntary membership organization with 255 current members from municipal utilities, interstate pipelines, distribution systems, and several foreign natural gas organizations. A 27-member board of directors, and a number of advisory groups which include representatives from public interest organizations, state regulatory commissions, federal and state government agencies, industrial research organizations, and natural gas companies provide guidance to GRI and help set its program priorities and overall budget goals.

GRI R&D PROGRAM GOALS

- Maximize Form Value of Gas to End Users
- Optimize Use of Gas in U.S. Economy
- Minimize Cost of Gas Production and Delivery
- Ensure Reliability of Gas Service
- Ensure Safety and Minimal Environmental Impact of Gas Supply, Storage, Transport, and End Use

In full operation only since 1978, GRI has developed a strong reputation for meeting the pressing technology needs of its member companies and their customers and of laying the foundation for future advances. All stakeholders in natural gas supply and use — producers, pipelines, distribution companies, manufacturers and ratepayers — benefit from the introduction of new technologies that increase the value of gas energy now and in the future. The tangible results of GRI's R&D programs reflect its overall goal: to use technology to enhance the benefits of gas energy, making the use of gas more productive, more convenient, and more economical than the competition — in today's marketplace and in tomorrow's.

REGULATORY REVIEW

- FERC-Approved Funding Unit on Interstate Gas Sales
- States Are Automatic Intervenors
- State Regulatory Approval on Intrastate Gas
- Protection of Ratepayer Interests
- R&D Benefits to All Sectors of the Gas Industry and Its Customers

The GRI R&D program is funded primarily through regulated sales of natural gas. The Federal Energy Regulatory Commission (FERC) authorizes GRI's 33 interstate pipeline company members to collect a funding unit as an integral element of the cost of gas in order to finance a national gas research program. Subject to appropriate state regulatory approvals, a number of member companies apply a similar charge to their intrastate sales.

The 50 state regulatory commissions and the District of Columbia Commission are automatic intervenors in the FERC proceedings. Eleven successive FERC rulings approving annual GRI R&D plans and budgets have been issued to date.

GRI'S R&D PROGRAM FOCUS

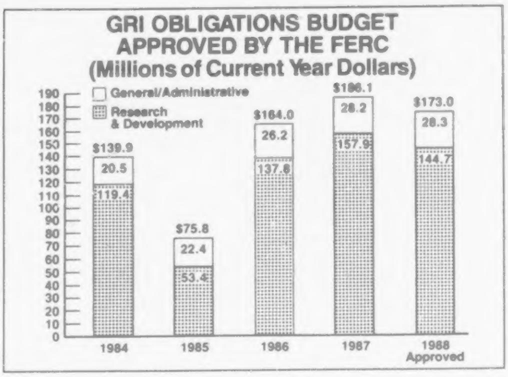
- Emphasis on Near-Term Research and Products Into the Marketplace
- No Funding Beyond Proof-of-Concept Stage Without Industry Involvement and Commercialization Plan
- More Than 44 GRI-Developed Products in Marketplace Since 1978
- 57 Information Items and More Than 160 Scientific Advancements

GRI's policy is to not pursue developments beyond proof-of-concept in any project without the direct involvement—and an intent to commercialize if the development is successful—by a manufacturer or major user. Since 1978, its first full year of operation, GRI has funded development of 364 applied research concepts, of which 145 have been completed or terminated. Of the 85 successfully completed applied R&D concepts, 44 products, processes and techniques for the residential, commercial, industrial, gas supply, and gas utility operations markets have been commercialized. In addition, 57 information items and over 160 scientific advancements have resulted from GRI-sponsored research.

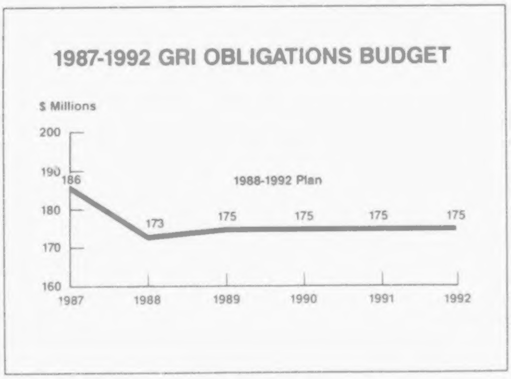
R&D RESULTS

- 364 Applied Research Concepts Funded
- 85 Successfully Completed
- 44 Products, Processes, and Techniques Have Been Commercially Accepted
  - 15 New Gas-Using Products
  - 5 New Developments to Reduce the Cost of Transporting Gas
  - 15 New Technologies Adopted by Producers and Service Companies to Reduce Exploration and Production Costs

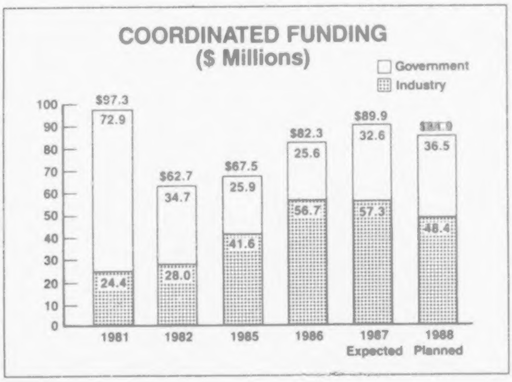
The Federal Energy Regulatory Commission (FERC), noted in Opinion No. 226 "it is beyond dispute that since its inception GRI's R&D has produced significant, tangible results of benefits to the gas-consuming ratepayers." Since then further progress has been achieved. An analysis of GRI's first 10 years showed that, of the 85 research concepts successfully completed to date by GRI, more than one-half have already resulted in a significant return on R&D investment. As a result of GRI-sponsored research, more than forty products, processes, and techniques are making important contributions in several critical areas, have opened new markets, have cut distribution and transmission costs, or have contributed to the optimistic outlook for Lower 48 natural gas supply at competitive prices.



The 1987 GRI program, as approved by FERC, is being funded at an obligations budget level of approximately $186 million ($157.8 million for R&D and $28.2 million for operating expenses). GRI's recently approved 1988 R&D budget is $144.7 million, a reduction of $13 million from the approved 1987 budget. GRI's R&D budget is distributed among four main program areas: End-Use, Supply, Operations, and Cross-cutting Research. A major portion of GRI's R&D budget is allocated to development of new, more efficient end-use technologies to help increase the competitiveness of gas in the residential, commercial and industrial markets.

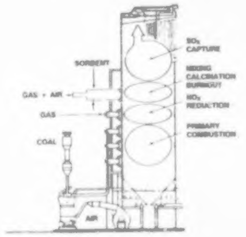


GRI's 1988 R&D Program and 1988-1992 R&D Plan, developed with the guidance of its Board of Directors, calls for a substantially lower level of expenses than that previously approved by FERC for the GRI program in 1988, and a no-growth budget over the next five years. This steady state funding approach will allow GRI to continue to build the necessary technology base for the gas industry and its customers, while at the same time meeting the challenge of bringing its funding into line with current gas industry conditions.



In addition to this ratepayer funding base, GRI's total level of funding is enhanced by cofunding and coordinated funding of specific projects by industry and the federal government. In 1988, GRI expects this supplemental funding to reach $36.5 million from the government and $48.4 million from manufacturers, major users, producers, and oil field service companies.

GAS REBURN/DRY SORBENT INJECTION SO_x/NO_x CONTROL



CLEAN COAL TECHNOLOGIES

Gas can reduce emissions and improve performance of industrial and power plant boilers both by supplementing other fuels and by enhancing combustion. GRI research in this area focuses on two retrofit technologies in particular. One uses gas to burn out nitrogen oxides. The other uses gas and an injected sorbent material to reduce sulfur dioxide. In one project, Energy and Environmental Research Corporation (EERC), a GRI contractor, is currently demonstrating these technologies as part of the Department of Energy's Clean Coal Technology program. Under this contract, field evaluation activities are being carried-out at three utility boiler sites in Illinois, with cofunding by DOE, GRI, and the Department of Energy and Natural Resources of the State of Illinois.

OPPORTUNITY IN WASTE INCINERATION

Up to 230 billion cubic feet of gas per year could be consumed in the incineration of hazardous wastes and an additional 80 billion cubic feet used at "garbage-to-energy" plants in the next decade, according to a recent GRI study conducted by Radian Corporation. Gas is an excellent auxiliary fuel for incineration processes and may also be used to reduce emissions of toxic substances, acid gases, and nitrogen oxides. To further explore this new potential market and use for gas, GRI is planning joint research with the Environmental Protection Agency and interested gas industry funding partners to gather data on the benefits of gas as an incineration fuel. Studies are also underway to evaluate new gas technology concepts, identify research issues, and provide guidance to future laboratory and field work.

EPA HEAVY DUTY ENGINE EMISSIONS STANDARDS

	NO_x	HC	CO	PARTICULATE
1988	6.0	1.3	15.5	0.60
1991	5.0	1.3	15.5	0.25 TRUCKS
				0.10 BUSES
1994	5.0	1.3	15.5	0.10 ALL

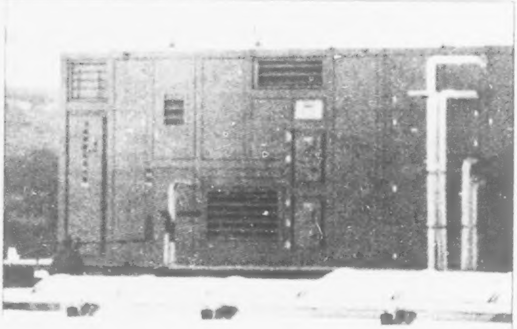
UNITS: g/(BHP-HR)

COMPRESSED NATURAL GAS TECHNOLOGY

In the late 1970s, increased gasoline and diesel fuel prices generated renewed interest in natural gas (both methane and compressed natural gas or CNG) as an alternative fuel in stationary and mobile engines. The development of new 1988 particulate standards by the U.S. Environmental Protection Agency (EPA) has renewed interest in CNG technology because, although the new standards cannot be met with the heavy duty diesel engines and exhaust systems on the market today, they can be met with CNG engines, or with combination CNG diesel engines that use existing diesel technology. GRI is supporting R&D aimed at further developing and refining CNG and CNG diesel engines. These projects include development of: a retrofit kit to help clean-up emissions from existing buses, an inexpensive add-on engine modification, and new dedicated CNG and CNG diesel engines for buses and heavy trucks—all of which will meet the new EPA standards.

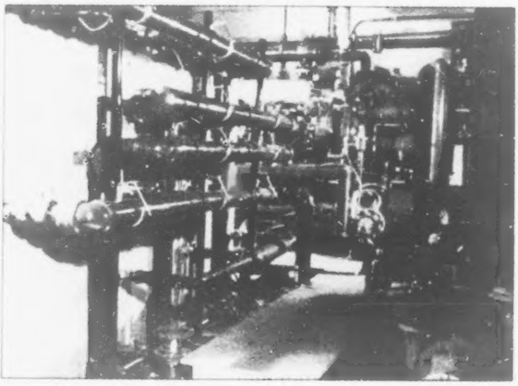
GAS HEAT PUMPS

To be successful in the residential space conditioning market, gas-fueled heat pumps must provide efficient heating and cooling, high reliability and performance, and significant energy and operating cost savings at a small installed cost premium over electric heat pumps. A reciprocating engine residential heat pump, developed for GRI by Battelle-Columbus Laboratories promises to do so in the next few years. The heat pump is expected to go into field experiment in January 1988, with field testing scheduled for mid-1989.



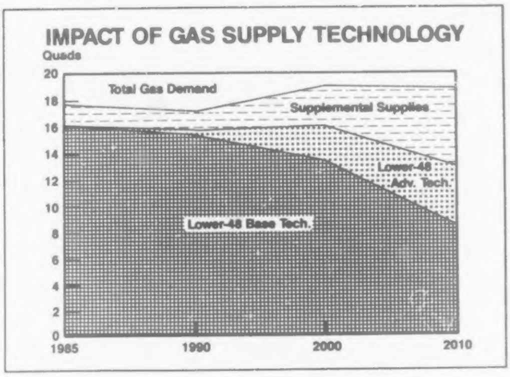
DESICCANT COOLING SYSTEM

In the commercial buildings market, GRI is committed to developing new gas technologies to provide users the cost-effective cooling service they are demanding. For low-rise buildings, one near-term option is desiccant-based systems in which gas is used to heat and regenerate a rotating desiccant wheel that dehumidifies air. GRI is working with Cargocaire Engineering Corporation to develop an advanced version of its "Superaire" desiccant system (also developed with GRI support) that is now providing new market opportunities for local companies and is saving owners of supermarkets across the country about $8,000 per year. The advanced system would potentially provide twice the annual savings of the present system and could be used in a variety of commercial buildings.



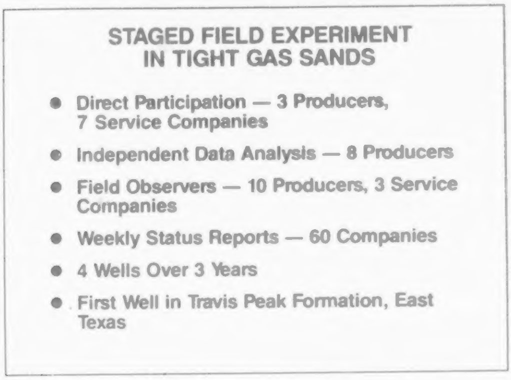
ABSORPTION CHILLER SYSTEM

For mid- and high-rise buildings, absorption chiller systems are expected to double the performance of gas cooling equipment now on the market. An absorption chiller-heater, developed by Hitachi as part of a GRI-sponsored cogeneration system, recovers engine waste heat and produces hot and chilled water for mid-sized commercial buildings. Recently introduced into the marketplace, the improved system increases performance and capacity of gas engine-driven systems over previous equipment by about 40 percent, and is also less complex, smaller, and costs less than other conventional equipment.



SECONDARY GAS RECOVERY

In response to the need for secure, ample, low-cost supplies of natural gas, GRI is supporting a comprehensive gas supply research program, with cofunding and/or coordination from numerous producer partners and the federal government. Included in this program are efforts to develop new methods for enhanced production of natural gas from already established fields, through the use of secondary recovery techniques. By addressing these research and development opportunities, it is estimated that two to four additional quads of gas reserves can be tapped in the near term at market clearing prices.

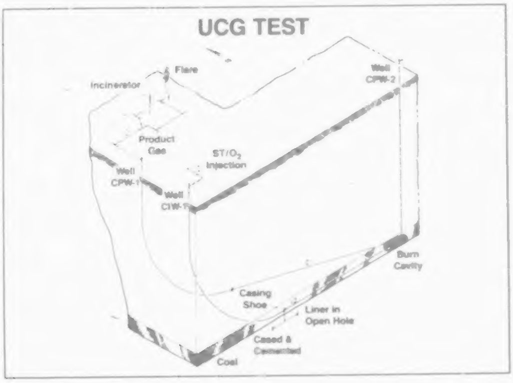


STAGED FIELD EXPERIMENT IN TIGHT GAS SANDS

- Direct Participation — 3 Producers, 7 Service Companies
- Independent Data Analysis — 8 Producers
- Field Observers — 10 Producers, 3 Service Companies
- Weekly Status Reports — 60 Companies
- 4 Wells Over 3 Years
- First Well in Travis Peak Formation, East Texas

STAGED FIELD EXPERIMENT

Through a series of field-based experiments performed in four research wells, GRI is supporting research aimed at reducing the cost of stimulating low-permeability gas reservoirs by developing the capability to predict hydraulic fracture growth and to control the process for optimum results. The experiments are being conducted in four stages — the first three in the Travis Peak/Hosston formation in east Texas and the remaining one yet to be determined — and provide a pseudo-laboratory field environment under which multiple sets of new tools and technology can be assessed.



UNDERGROUND COAL GASIFICATION

Underground coal gasification offers a method for recovering coal resources, without the need for mining, by gasifying the coal in-place underground. Oxygen, in conjunction with steam, is injected into an underground coal bed to drive and control the gasification reactions. A project to test this technology is currently underway at the Rocky Mountain I site in Hanna, Wyoming. The project is co-funded by DOE, GRI, EPRI, Amoco, and Union Pacific Resources, and is being carried out by Stearns-Roger. The gasification phase of the project is expected to be completed in February, 1988. Environmental work should be completed in early 1989, with post-burn monitoring continuing for five years.

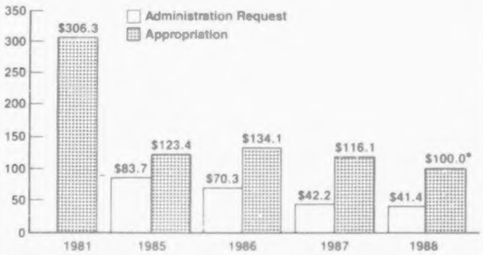
INDUSTRIAL PARTICIPATION 1986 COORDINATED FUNDING ($M and %)

Category	(no. of companies)	($M–%)
Industrial Equip. Mfg.	51	$10.2-22.3%
Appliance Mfg.	18	2.5- 5.5
Gas Equip. Mfg.	21	1.0- 2.2
Oilfield Service	14	1.3- 2.8
Producers	64	14.2-31.1
Major Users	65	21.7- 9.9
Distributors	65	3.9- 8.5
Pipelines	13	2.7- 5.9
International	25	
TOTAL	336	$45.7
University, International, and Other		11.0
TOTAL INDUSTRIAL COFUNDING		$56.7

An important measure of performance for an institutional R&D organization is the ability to attract the involvement of other organizations in its R&D projects. This involvement eases some of the funding burden on the organization's principal supporters and provides a path to commercial application of the technology.

In 1986, industry coordinated funding from more than 300 industrial partners, as well as from universities and other national and international research organizations, reached a level equal to 33 percent of GRI's total R&D program. All sectors of the natural gas production, distribution, and end use chain are actively represented at GRI/industry cofunders, as are the manufacturers of the equipment used by the industry and its customers.

GAS-RELATED RESEARCH ($ Millions)



*Approximation

GRI and its industrial partners have consistently responded to the Administration's challenge to fund and conduct near-term energy research, while, at the same time, responding to the gas industry's overall R&D needs. The federal government must respond in kind by fulfilling its commitment to long-term technology developments, while maintaining a balanced energy policy and consistently meeting the funding needs of on-going programs. Congress has been supportive of increased funding levels to carry out ongoing gas-related research projects which help address our nation's future energy needs. Continued Congressional support is required to fund these critical gas-related research projects and technology developments.

GAS INDUSTRY RECOMMENDATION DOE GAS-RELATED FUNDING FY 1989 ($ Millions)

ARTD	$ 6.0
Fuel Cells	22.7
Surface Coal Gasification	15.0
Underground Coal Gasification	1.75
Unconventional Gas	20.0
Heat Pumps	7.0
Industrial Cogeneration	5.0
Indoor Air Quality	3.0
Energy Conversion & Utilization Tech.	7.0
Desiccant Systems	2.0
Biofuels	8.0
Liquid Spill Test Facility	1.5
Geopressured Resources	10.4
NGV/Diesel Vehicles	5.0
TOTAL	$114.35

In order to meet the challenge to provide a balanced energy policy and utilize the nation's abundant and cleanest burning fuel wisely, GRI and the gas industry have offered their recommendations for a logical, balanced federal role in long-term, gas-related R&D. In FY 1989, the gas industry's recommended federal budget of $114.35 million in gas-related research will allow DOE to maintain viable funding levels for continuing long-term R&D programs and cofunded projects in several critical areas including underground coal gasification, unconventional natural gas, and gas heat pumps.

Mr. CHAPMAN. Thank you, Mr. Webb. Dr. Lee, you may proceed.

STATEMENT OF DR. BERNARD S. LEE, PRESIDENT, INSTITUTE OF GAS TECHNOLOGY, CHICAGO, IL

Dr. LEE. Thank you, Mr. Chairman and Members of the Subcommittee. I am Bernard Lee, President of the Institute of Gas Technology, an organization dedicated to energy research.

Since I testified a year ago, the energy situation has not improved. Domestic production continues to decline and imports continue their rise, accounting for 44 percent of our present oil supply.

Last year the U.S. spent an estimated $40 billion on oil imports, almost one-third of the country's trade deficit. Ultimately, our growing dependence would allow OPEC to once again affect U.S. economic stability and national security.

A strong and balanced energy research program across the entire R&D process, from test tube to commercial application, is the Nation's insurance policy against the vagaries of the free market and the whims of those who can withhold supply to achieve political objectives.

Unfortunately, in terms of Government energy R&D spending as a percentage of gross domestic product, the U.S. is in tenth place in the world. Such inattention to our country's energy future must be corrected to avoid disaster.

To some, energy is no more than another commodity to be traded like gold, cotton or wheat. I don't subscribe to this simplistic view. Energy is the fundamental driving force for human advancement and the foundation of an industrialized society. Thus, while we can do without gold by using other decorative materials, or cotton, by using synthetic fibers, or wheat, by eating other grains, we cannot do without energy.

We must understand that energy is not a commodity but a national priority like health, environment and defense, and that the necessary support for R&D, particularly in the long-term supply of energy, must come from the public sector.

Now this does not mean that we should take a shot-gun approach to energy R&D funding, nor repeat the past swings from indifference to crash programs. A successful national energy R&D program requires commitment and discipline; commitment by the Government to provide appropriate levels of funding, and discipline by the R&D community to translate that commitment into an orderly execution of the development plan.

For fiscal year 1989, I support the gas industry budget recommendation of $114 million. IGT specifically recommends the following.

In areas of fuel cells, we have just signed a contract with DOE for a two-year program to develop the molten carbonate fuel cell system based on the internally-manifolded IMHEX concept. This unique stack design concept will reduce cell costs as well as the cost of electricity produced. In order to ensure that this technology will reach its full potential, IGT recommends $8.5 million in fiscal year 1989 to continue design, development and testing of the innovative IMHEX stacks under DOE contract.

IGT has been developing a contaminant-resistant molten carbonate fuel cell which will eliminate the cost of cleaning the fuel gas to a very low contaminant levels. This generic research was not folded into the stack development program of DOE. Therefore, we recommend $1.5 million to develop methods for fabricating components using the best contaminant-resistant geometry and testing these components in short stacks.

IGT has just begun research on two advanced concept fuel cells. One, the advanced alternate planar geometry solid oxide fuel cell would accept greater thermal stress without cracking and has improved electrical properties and stability. The other solid oxide proton conductor fuel cell has the potential to produce higher efficiencies and longer life than existing fuel cell concepts, and as a result, a lower operating temperature and lower electrode polarization.

IGT therefore recommends $1 million to develop and scale up the advanced alternate planar geometry solid oxide fuel cell, and $0.5 million to continue development of the solid oxide proton conductor fuel cell.

In the areas of coal, with a forecasted increase in the use of coal and the development of clean coal technologies, there must be a unified approach to developing the necessary technology base. As a part of this base, we recommend $1 million for the continued funding of the development of an advanced mild gasification process; $0.5 million for the development of the TADCO microbial coal gasification process in a program to be cofunded by the Gas Research Institute; $2.5 million for a cofunded research program with the State of Illinois to prove operation of an ash agglomerating coal gasifier with limestone addition at pressures of up 500 PSIG; and, $2.5 million for research on advanced two stage coal combustor utilizing the existing eight inch diameter, sloping grid, fluidized bed reactor in order to cost effectively reduce pollutants from all types of coal.

In the area of conservation, to increase the efficiency of air conditioners and heat pumps, IGT has developed the Hyperabsorption Cycle concept. We expect this system to cost less than advanced systems and operate as simply as the basic absorption cycles. We therefore recommend $1.5 million to support the development, construction and testing of a prototype gas-fired Hyperabsorption Cycle heat pump.

In the area of geopressured resources, for several years IGT has been a part of a DOE project aimed at solving the technical issues associated with the production of cost competitive natural gas from the vast resource in geopressured reservoirs in the Texas/Louisiana Gulf Coast.

We recommend $10.4 million to continue the existing contracts for a scientific design acquisition and analysis from the Pleasant Bayou and Gladys McCall Wells, and for rehabilitation of the Hulin Well.

Finally, in the area of natural gas use for diesel vehicles, IGT has conceived a method of improved onboard storage for natural gas transportation fuel for heavy duty trucks and bus fleets, as contrasted to current work which concentrates on commuter cars and light duty utility fleet vehicles.

We recommend $1.6 million to further develop the VE-GAS absorption storage system, including the required heat management approaches, to use natural gas as a fuel for heavy duty urban bus and truck fleets.

Mr. Chairman, I thank you for your attention. We appreciate the support of you and the Committee for the past R&D efforts that needed to be done. Thank you.

[The prepared statement of Dr. Lee follows:]

STATEMENT BY BERNARD S. LEE
PRESIDENT, INSTITUTE OF GAS TECHNOLOGY
HOUSE COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT

March 3, 1988

Madame Chairman and Members of the Subcommittee:

As president of the Institute of Gas Technology, I feel I can bring you a unique perspective on energy, different from that of an energy producer, consumer, regulator, or policymaker. I like to think of IGT's role as that of a performer of research which serves as a bridge to enable technology to move from fundamental development to the marketplace.

As a not-for-profit organization, totally dedicated to hands-on, experimental work from test tube to commercial application, we think that a balanced distribution of funding across the entire research and development process is crucial. Few would plan a new highway for both sides of a river without allocating sufficient funds for a connecting bridge: The effectiveness of a research program will be undermined if promising programs identified by fundamental research are left to die before industry has enough information to judge the commercial applicability of the ideas.

Since I testified a year ago, the energy situation has not improved overall. Although oil prices have recovered somewhat from their 1986 free fall, domestic production continues to decline. Last year, the Office of Technology Assessment warned that, if prices stayed in the $12-$18/bbl range, domestic production would be likely to drop from 9 million bbl/day in 1985 to 6-7 million bbl by 1990. Meanwhile, imports continue their steady rise, accounting for 44% of our present oil supply.

Last year, the U.S. spent an estimated $50 billion on oil imports, almost a third of the country's trade deficit. Although this makes oil imports the second largest single import expense after automobiles, most forecasts indicate that oil imports are likely to regain first place soon, regardless of the trend in oil prices. Ultimately, our growing dependence could allow OPEC to regain power in the oil market to affect U.S. economic stability and national security.

A strong and balanced energy research program is a nation's insurance policy against the vagaries of the free market and the whims of those who can withhold supply to achieve political objectives. The technologies that emerge from a sustained energy research program can help to reduce our vulnerability to external threats, both economic and military, reduce domestic costs of energy, provide industry with the energy it needs to compete in future world markets, and help the country achieve a reasonable balance of trade.

In general, countries that have devoted a larger share of their resources to non-defense research and development have experienced more rapid economic growth. A lagging economy must purchase research and development from others; a leading economy can produce its own technologies to achieve world leadership. This is equally true of energy RD&D - an area where this nation is rapidly losing the lead it once enjoyed. In 1986, for the first time, Japan surpassed the United States in its government expenditures on energy RD&D. In terms of government RD&D spending as a percentage of Gross

Domestic Product, the U.S. is in tenth place. Such inattention to our country's energy future must be corrected to avoid disaster.

To some, energy is no more than another commodity to be traded, like gold, cotton or wheat. As such, it should be left to the market to determine its value.

I do not subscribe to this simplistic view. I believe that energy is special. It is not like gold, cotton or wheat. Energy is the fundamental driving force for human advancement, and the foundation of an industrialized society. Thus, while we can do without gold, by using other decorative materials, or cotton, by using synthetic fibers, or wheat, by eating other grains, we cannot do without energy.

No major industrial nation can long survive, let alone prosper, primarily as a distributor or consumer of products manufactured elsewhere. A reasonable amount of service and international trade is desirable and beneficial. But, without an adequate manufacturing base, there would be no foundation on which to support the service industry; and without energy, there cannot be a broad manufacturing base. A primarily service-oriented economy is not an option for any major power that influences the world economy and participates in maintaining a free world. Once it is accepted that energy transcends the market, goals must be defined to achieve energy security as a basic public necessity.

We must understand that energy is not a commodity, but a national priority, like health, environment, and defense, and that the necessary support for R&D, particularly in the long-term supply of energy, must come from the public sector.

In its recent report, "R&D Initiatives for Energy Competitiveness," DOE's Energy Research Advisory Board argues that the effective use of energy in a country's economy is an important determinant of its international competitiveness. This includes its performance in reducing energy intensity and oil use, diversifying energy sources, and promoting new energy technologies. ERAB claims it is in these areas that other nations are outperforming the U.S., thereby gaining a competitive advantage.

The reason is not that the U.S. lacks the technology necessary to enhance its energy competitiveness nor is incapable of developing new technologies. The chief obstacle is uncertainty, both in the marketplace and in government policy. R&D policy presents special problems, because the risks inherent in it are imperfectly dealt with by capital markets, "R&D investment tends to be less attractive than other forms of investment because R&D's product is innovation, the benefit of which is usually very difficult to retain completely within the innovating organization," says ERAB.

And while energy R&D can help to mitigate the effects of an oil supply disruption or the threat of disruption, the private sector has little economic incentive to conduct energy R&D. Thus, the government has a critical role to play both in supporting R&D and in developing the institutional framework that will encourage industry to do so. "We believe that the national interest would be served by a faster pace of development and deployment of energy technology," is ERAB's conclusion.

This does not mean we should take a shotgun approach to energy R&D funding nor effect a repetition of past swings from indifference to crash programs. A successful national energy R&D program requires commitment and discipline: commitment by the government to provide appropriate levels of funding, and discipline by the R&D community to translate that commitment into an orderly execution of the development plan.

In a sensibly planned energy future, I see a need for research beyond what is proposed by DOE for funding in FY'89, and I support the gas industry's budget recommendation of $114.35 million. IGT specifically recommends the following:

Fuel Cells

IGT has recently signed a contract with DOE for a two year program to develop the optimum coal-fueled Molten Carbonate fuel cell system based on the internally manifolded IMHEX concept. This unique stack design concept will reduce cell costs as well as the cost of electricity produced. In order to ensure that this technology will reach its full potential,

*IGT recommends $8.5 million be provided in FY'89 to continue design, development, and testing of the innovative IHMEX stacks, under the DOE contract.

IGT has been developing a contaminant resistant MCFC which has the potential to prevent the degradation in cell performance due to contaminants, without incurring the costs of cleaning the fuel gas to very low contaminant levels. This generic MCFC research was not folded into the stack development program therefore,

*IGT recommends $1.5 million to continue to develop methods for fabricating components using the most viable contaminant resistant geometry and testing these components in short stacks.

IGT has just begun research on two advanced concept fuel cells. One, the advanced Alternate Planar Geometry solid oxide fuel cell would accept greater thermal stress without cracking, and has improved electrical properties and stability. The other advanced concept, Solid State Proton Conductor fuel cell, is unique in having the potential to produce higher efficiencies and longer life than existing fuel cell concepts as a result of lower operating temperature and lower electrode polarization.

*IGT recommends $1.0 million to further develop and scale-up the advanced Alternate Planar Geometry SOFC, and $0.5 million to continue development of SSPC fuel cell.

Coal

With a forecasted increase in the use of coal and the development of clean coal technologies, there must be a unified approach to developing the necessary technology base. As a part of this base, IGT recommends the following:

*$1.0 million for the continued funding of the development of an advanced mild gasification process.

*$0.5 million for the development of the TADCO microbial coal gasification process in a program to be cofunded by the Gas Research Institute.

*$2.5 million for a cofunded research program with the State of Illinois to prove operation of an ash agglomerating coal gasifier with limestone addition up to 500 psig.

*$2.5 million for research on the advanced two stage coal combustor (ATCCO) utilizing an existing eight inch-diameter, sloping-grid, fluidized-bed, in order to cost effectively reduce pollutants (NOx, SOx, and particulates) for all coal types.

Conservation

In response to the need for higher efficiency air conditioners and heat pumps IGT has developed the Hyperabsorption Cycle concept. We expect this system to cost less than advanced systems and operate as simply as the basic absorption cycles.

*IGT recommends $1.5 million to support the development, construction, and testing of a prototype gas-fired, Hyperabsorption Cycle heat pump.

Geopressured Resources

For several years, IGT has been part of a DOE project aimed at solving the technical issues associated with the production of cost competitive natural gas from the thousands of trillions of cubic feet present in geopressured reservoirs in the Texas/Louisiana Gulf Coast. To continue the program in FY'89,

*IGT recommends $10.4 million to continue the existing contracts for scientific data acquisition and analysis from the Pleasant Bayou and Gladys McCall Wells, and for the rehabilitation of the Hulin well.

NGV/Diesel Vehicles

IGT has conceived of a method of improved on-board storage for natural gas as a transportation fuel for heavy duty urban trucks and bus fleets. Current work has concentrated on commuter type personal or light duty utility fleet vehicles.

*IGT recommends $1.6 million to further develop the VE-GAS absorption storage system, including the required heat management approaches, in order to use natural gas as a fuel for heavy duty urban bus and truck fleets.

Thank you for the opportunity to testify. I will be happy to answer any questions.

Selected Energy Research
Recommendations FY'89

PROGRAM FACT SHEET

INSTITUTE OF GAS TECHNOLOGY

FUEL CELLS

IMHEX Molten Carbonate Fuel Cell Stack Program

An integrated coal gasifier/molten carbonate fuel cell power plant can utilize our abundant domestic coal resources to produce electricity in a clean and environmentally acceptable manner with projected higher efficiencies and lower costs than competing advanced technologies. IGT has conceived of IMHEX, a unique approach to MCFC stacks. In this design, the reacting gases are distributed to each cell through internal channels in the fuel cell stack (hence the term internally manifolded) rather than through external piping as is used in other MCFC approaches. The IMHEX concept will also simplify stack assembly and reduce gas and electrolyte loss which have limited stack life in other MCFC designs. All of these factors will combine to reduce MCFC costs as well as the cost of electricity produced from MCFC systems. IGT has begun, under a contract with the Department of Energy, to determine the optimum coal-fueled MCFC system based on the internal manifolded IMHEX concept, and to continue the design, development, and testing of IMHEX stacks.

IGT recommends $8.5 million to continue stack development and testing of the innovative IMHEX molten carbonate fuel cell.

Contaminant Resistant and Endurance Related Issues

Molten carbonate fuel cells show significant performance degradation when exposed to contaminants such as sulfur and chlorine which are found in the product gas from coal gasifiers. DOE has been funding at IGT the development of a contaminant resistant molten carbonate fuel cell which has the potential to prevent the degradation in cell performance due to contaminants without incurring the costs of cleaning the fuel gas to very low contaminant levels. IGT is identifying the most promising fuel cell materials and the most viable fuel cell geometry.

IGT recommends $1.5 million to develop methods for fabricating components using the most viable contaminant resistant geometry and testing these components in short stacks.

Advanced Alternate Planar Geometry Solid Fuel Cells

Solid oxide fuel cells (SOFC) have the potential to produce electricity at high efficiency while producing high temperature by-product steam for cogeneration or electric power production applications. The tubular and monolithic SOFC's have been under development for many years but have been unable to solve the cracking resulting from thermal stresses. Flat plate (or Planar) SOFC's have had difficulty in fabricating sufficiently flat components and were also subject to thermal stress cracking.

The DOE is now supporting Ceramatec/IGT in the development of a novel planar SOFC concept which will accept greater thermal stress without cracking, and which has improved electrical properties and stability. This concept, because of its planar configuration, uses low cost fabrication methods to produce a readily scalable high performance SOFC.

IGT recommends $1.0 million to accelerate the development and scale-up of the Advanced Alternate Planar Geometry SOFC.

Solid State Proton Conductors Fuel Cells

Solid State Proton Conductors Fuel Cells (SSPC) are a new alternative to existing fuel cell technologies. In a proton conductor fuel cell, the electrolyte, an ionic solid conductor, transmits protons (Hydrogen ions) creating the current. They have the potential to provide superior performance, cost, and life over current fuel cells and other competing technologies. The SSPC is unique in that it has the potential to produce higher efficiencies than other fuel cell concepts and deliver longer life as a result of the solid state electrolyte.

The U.S. Department of Energy has awarded a contract to IGT for the selection of materials and development of a SSPC fuel cell.

IGT recommends $0.5 million to continue and accelerate the development of SSPC fuel cells.

COAL

Development of an Advanced Mild Gasification Process

The demand for oil in the United States is increasing, while the utilization of its largest fossil energy resource, coal is steadily decreasing. The U.S. Department of Energy has estimated that the displacement of 25% of the non-coal fuels used by the light industrial, commercial, transportation, and large multifamily residential sectors by coal could boost current coal consumption by 50%. A coal conversion technology that is affordable in the present economic climate and which could be commercialized in the near future, would significantly benefit both the Nation and the coal industry. The gasification of coal at milder temperatures produces a wide range of products suitable for use in sectors now heavily dependent upon oil. The development of an advanced mild gasification process is anticipated to result in the production of economically competitive, marketable co-products.

A DOE-sponsored effort for the development of an advanced mild gasification process is currently being conducted by a team consisting of IGT, Peabody Holding Co., Inc., Bechtel National, Inc., and Caterpillar, Inc. IGT, as the prime contractor, is conducting the bench-scale and process development unit system studies in existing equipment. Peabody is advising IGT to ensure that research objectives are consistent with the needs and goals of the coal industry, Bechtel is responsible for conducting market assessments for co-products and for technical and economic process evaluations, and Caterpillar is evaluating the suitability as a heat engine fuel of the liquids produced.

The goals of the research program are to demonstrate the advanced mild gasification process, to verify the marketability of the co-products and the economic viability of the process, and to ensure that all environmental concerns are adequately addressed. The project team members will then develop a marketing plan and commercialization strategy.

IGT recommends $1.0 million for the continued funding of the development of an advanced mild gasification process.

Development of the TADCO Coal Gasification Process

Conventional thermal gasification of coal is conducted at high temperatures. The development of a process that would operate at much lower temperatures has the potential to reduce both capital and operating costs for coal gasification. Microbial coal gasification is conducted at much milder temperatures than conventional gasification, but its practicality has previously been limited due to the long processing time required.

The basis for microbial processing of coal is well established. Research currently being conducted at IGT and other organizations under DOE sponsorship has proven that microbial coal solubilization can be effectively accomplished. IGT, which has considerable experience in both thermal and biological processing of coal, is well aware of the limits of the subsequent gasification of the solubilized coal via traditional biological concepts.

In order to overcome these limitations, IGT has developed a concept for a novel two-stage biological gasification method that would greatly reduce the required coal processing time and improve the quality of the product gas. IGT has also conducted an internal research and development project resulting in the development of a microbial coal pretreatment method that would reduce the total processing time even further. These advances are incorporated in the IGT TADCO process, which is a major improvement when compared to state-of-the-art microbial gasification processes.

IGT recommends $0.5 million for the development of the TADCO coal gasification process in a program to be cofunded by the Gas Research Institute.

Extending Pressurized Operation of Ash Agglomerating Gasification

Studies have shown that simplified integrated gasification/combined cycle (IGCC) has the potential to produce power at high efficiencies with attractive capital costs. However, for this application, the fluidized-bed gasifier has to operate at a pressure of 500 psig or higher. At high pressure, fluidized-bed gasifiers have the advantage of being able to gasify all types of coals and the capability to accept coal fines in the gasifier feed.

While there is performance data for operation of an ash agglomerating gasifier at lower pressures, data for operation of the gasifier at higher pressure is needed to determine the impact on the gasification and agglomeration process. Operation of the gasifier at 500 psig or higher may affect the range of conditions over which ash agglomerates can be formed for specific coals. Sulfur absorption reactions may be altered, and the amount of fines that will be carried over from the gasifier and the potential effect on the hot gas cleanup system need to be evaluated.

Initial scoping tests have been conducted by IGT at up to 450 psig operating pressure with favorable results. These preliminary results warrant a planned and coordinated program to demonstrate the operation of the ash agglomerating gasifier at 500 psig or higher and to provide data that will be correlated with pilot plant data at lower operating pressures.

The high pressure gasifier that would be used in this program has been constructed using IGT's own funds, and a considerable low pressure data base has been acquired under GRI sponsorship. It is anticipated that cofunding for the two year, $5.75 million program will be provided by the State of Illinois and others.

IGT recommends $2.5 million for a cofunded research program to demonstrate operation of an ash agglomerating gasifier at 500 psig or higher.

COAL COMBUSTION

Advanced Two Stage Coal Combustor (ATCCO)

The major challenges facing coal combustion today are to find more cost effective ways to reduce the pollutants (NOx, SOx, and particulates) while producing a non-leachable ash. The state-of-the-art in coal combustion is the circulating fluidized bed combustor or CFBC. While CFBC is more efficient than conventional coal combustion, it is necessary to develop a third generation combustion system that will enable cleaner, more cost effective combustion of coal, particularly high sulfur coal.

A commercial CFBC has an inert fluidizing media within the bed. The CFBC is operated to ensure complete combustion of coal and to remove the SOx from the sulfur in the coal by adding limestone. However, CFBC does not suppress the formation of NOx. Attempts to reduce NOx by first gasifying the coal result in leachable sulfur compounds in the ash. The CFBC is also designed so that all of the coal ash exits the top of the vessel withthegas. The ash must then be removed mechanically (cyclones, baghouse or electrostatic precipitator.

IGT has invented an advanced two-stage coal combustor (ATCCO) that will result in greatly reduced formation of NOx, significantly lower particulate emissions, and a non-leachable ash. The first stage of the IGT ATCCO is a fluidized bed which operates under reducing conditions so that most of the nitrogen in the coal is converted to molecular nitrogen, and not to NOx. Limestone is injected to promote the capture of sulfur in solid form. The fluidized bed stage of the ATCCO employs a patented sloping grid that causes agglomeration of the ash particles. The ash agglomerates and the spent limestone exit the bottom of the vessel through an oxidizing zone that renders the agglomerates. There is limited carryover of solids to the second stage of the ATCCO, which is a cyclonic combustor/separator. High intensity, high efficiency combustion of the gases from the first stage takes place in the cyclonic combustor under conditions which further minimizes the formation of NOx and SOx. Fines are separated from the gas in the cyclonic combustor and returned to the first stage fluidized-bed.

The advantages of the ATCCO are removal of sulfur and ash in the form of easy-to-handle, non-leachable, granulated solids from the bottom of the fluidized bed; low formation of NOx, and minimal carryover of fines from the cyclonic combustor.

The last feature results in a smaller, more economical baghouse and extended boiler tube life. Once the ATCCO has been developed for coal combustion, it could also be used for incineration of various industrial waste materials.

IGT recommends $2.5 million for research on the advanced two stage coal combustor utilizing an existing eight-inch-diameter sloping-grid fluidized-bed.

CONSERVATION

Development of the Hyperabsorption Cycle Heat Pump

During the last decade, both government and private industry have attempted to develop high efficiency absorption air conditioners and heat pumps for the residential and small commercial space conditioning markets. Absorption heat pumps use the heat involved in evaporation from, and subsequent absorption of a refrigerant into, a refrigerant absorbent solution to accomplish the heating or cooling, rather than using a compressor as in a traditional electric heat pump or air conditioner.

The basic absorption cycle has a heating coefficient of performance (COP) approaching 1.2 and a cooling COP between 0.5 and 0.7. The advanced systems, many of which have been abandoned either due to low efficiency or high first cost, are all evolutionary designs based on the basic absorption cycle. None of these advanced systems have yet reached the preproduction prototype stage; they all suffer from high first cost and/or high system complexity.

IGT has developed a revolutionary high-efficiency cycle concept, the Hyperabsorption Cycle. The simplest version of this hyperabsorption Cycle has the potential to yield heating and cooling COP's of 2.2 and 1.3 respectively, higher than that obtained by the advanced and more complex, versions of the absorption cycle. It is expected that the Hyperabsorption Cycle System will cost less than the advanced systems and operate as simply as the basic absorption cycles.

IGT's expertise in heat pumps and refrigerants coupled with the mechanical and heat exchange capabilities of its mechanical systems partner provide the skills necessary to successfully design, construct, and operate a developmental prototype Hyperabsorption Cycle heat pump. Such a prototype is necessary to demonstrate technical feasibility, performance, and equipment cost.

IGT recommends $1.5 million to support the development, construction, and testing of a prototype gas-fired Hyperabsorption Cycle heat pump.

BIOFUELS

Pressurized Gasification of Refuse Derived Fuels

The disposal of municipal solids waste is becoming an increasingly crucial issue in many parts of the United States. In an attempt to minimize the volume of waste materials that must be landfilled, many resource recovery projects incorporating recycling and/or waste-to-energy plants are in the planning and development stage.

The waste-to-energy facilities primarily employ mass burn technologies, in which the waste is incinerated, producing steam which can then be used to produce electric power for district heating purposes. Some waste-to-energy facilities manufacture refuse derived fuel (RDF), which is produced by separating the lighter, mostly cellulosic materials, which can then be pelletized and used to augment coal in boilers.

There are many problems associated with mass burn and RDF facilities. Over 72% of the existing resource recovery plants have suffered extended duration shutdowns for reasons other than normal maintenance. The problems associated with the mass burn facilities are mainly equipment related, while the problems with RDF facilities are related to unfavorable process economics. Due to the relatively high ash content of RDF, boiler maintenance is increased so there is little incentive for the operator of a coal fired boiler to use RDF.

IGT has developed the pressurized, fluidized-bed RENUGAS process for the gasification of biofuels, and has successfully applied it to selected industrial wastes. The modification of the RENUGAS process for the gasification of RDF offers the advantage of very high conversion of carbon to a fuel gas at a pressure high enough for efficient gas turbine operation. The production of a valuable product, electric power, in an efficient combined cycle power plant will improve the economic viability of RDF plants by providing a valuable market for their product.

IGT recommends a research and development program in which an existing process research unit will be utilized for conducting parametric RDF presssurized gasification tests, and evaluating RDF feeder design.

IGT recommends $1.0 million in FY 1989 for an RDF pressurized gasification program utilizing the RENUGAS process.

GEOPRESSURED RESOURCES

Geopressured Methane

The U.S. Department of Energy has a project aimed at solving the technical issues associated with the production of cost competitive natural gas from the vast resource (thousands of TCF) present in geopressured reservoirs in the Texas/Louisiana Gulf Coast. The project has available three specially designed and drilled geopressured/geothermal wells, Gladys McCall, Pleasant Bayou, and Hulin. Scientific tests are underway at Gladys McCall to determine reservoir production mechanisms; the Pleasant Bayou surface equipment has been completed and the cost shared EPRI hybrid power plant will shortly be installed: and it is planned to rework the Hulin well to prevent a potential environmental hazard and to allow for subsequent testing of this deepest of the three wells. These tests will provide for a better understanding of the scientific principles involved with producing energy from this resource and will lead to reduced industry cost and risk.

IGT recommends that $10.4 million be provided for the continuation of existing contracts for scientific data acquisition and analysis from the Pleasant Bayou and Gladys McCall wells, and for the rehabilitation of the Hulin well.

NGV/DIESEL VEHICLES

Enhanced Gas Storage for Vehicular Use

Vehicles using natural gas as a fuel have the advantage of producing very low pollution while using an abundant domestic natural resource. One key to using natural gas as a fuel in transportation applications is an improved on-board method of storage.

The Institute of Gas Technology's VEhicular-GAS concept employs novel storage technology to allow the use of natural gas as a vehicular fuel. The technology, adsorption storage, permits on-board storage of natural gas that is comparable to conventional storage methods that use compressed natural gas (CNG) or liquefied natural gas (LNG), but without requiring the very high pressures of CNG or the very low cryogenic temperatures of LNG.

Scale-up of the VE-GAS concept is currently underway at IGT for commuter-type personal vehicles capable of slow, overnight home-refueling from existing gas services. IGT's efforts on fast-filling of light-duty utility fleet vehicles (pickup trucks and vans) have shown that the addition and removal of heat during the discharge and charge cycles is an obstacle which the VE-GAS concept can potentially overcome.

Urban air quality could be significantly improved through the reduced gaseous and particulate emissions obtainable if heavy duty urban truck and bus fleets could use natural gas. This scale-up, however, requires the development of both the means to quickly refuel the large onboard fuel storage systems and the means to deliver fuel from storage at a rate matching the fuel demand of the large vehicle engines. The technical approaches for the small vehicles are not the same as those applicable to large systems such as gas cooling, recirculation with heat exchange, etc. Inexpensive fuel tank designs and their integration into the vehicle are tasks for a comprehensive storage system.

IGT recommends $1.6 million to further develop the VE-GAS adsorption storage system, including the required heat management approaches, in order to use natural gas as a fuel for heavy-duty urban bus and truck fleets.

Mr. Chapman. Thank you, Dr. Lee. Dr. Jones, you may proceed.

STATEMENT OF DR. VERNON T. JONES, PRESIDENT, THE WILLIAMS COS., AND CHAIRMAN, INTERSTATE NATURAL GAS ASSOCIATION OF AMERICA, WASHINGTON, DC

Dr. Jones. Thank you, Mr. Chairman. First, let me characterize my title as doctor. I do happen to hold such a title, but it is purely honorary. My name is Vernon Jones. I am President of The Williams Companies. Our company operates two major interstate gas pipelines, one of which serves the midcontinent area and the other serves the Pacific Northwest.

I am appearing today as the Chairman of the Interstate Natural Gas Association of America to express our views on the 1989 Research and Development Budget for the Department of Energy.

Natural gas is a national resource, vital to our economic well being, our environmental goals, and our national security requirements. Natural gas is a predominantly domestic resource, whose production, transmission, distribution and consumption helps generate jobs and enhance the economic activity in all the regions of the United States.

The Department of Energy has an extremely key role to play in assuring the continued availability of natural gas at competitive prices. One way the Department can do this is through the judicious use of Government funds to support needed R&D projects, that the private sector cannot adequately address alone.

The industry's research arm, the Gas Research Institute or GRI, has for years coordinated research directions with DOE. An adequately-funded DOE R&D program is critical to the gas industry not only on its own merits, but also, because of the support and enhancement it provides to private organizations like GRI in public and private partnerships.

Overall, INGAA recommends funding DOE's R&D at $114 million, which is in line with the funds appropriated by Congress for fiscal year 1988. Of this total, we think that about $67 million should be allocated for Fossil Fuel R&D; $24 million for conservation R&D; $18.4 million for renewable energy source R&D; and, $5 million for natural gas vehicle R&D.

My written statement goes into much greater detail about the industry R&D proposal, but let me highlight just a few of those.

For programs aimed at unconventional gas recovery, we recommend a funding of $20 million. There is, we believe, firmly up to 2,000 trillion cubic feet of gas locked up in so-called tight formations. An effective R&D program is needed to improve the economics of production from these formations.

For research into the production of gas from geopressured brines, we recommend spending $12.4 million. In the Texas and Louisiana Gulf Coast, geopressured brines contain vast amounts of dissolved methane, the main component of natural gas. This resource could become a virtually unlimited supply of natural gas.

The DOE research in this area should be accelerated and redirected to concentrate on ways to recover even a small fraction of the dissolved methane from these geopressured formations.

INGAA recommends an allocation of $7 million to help in the development of natural gas heat pumps. Gas-based heat pump systems can achieve efficiencies of 25 to 50 percent greater than those of typical gas furnaces.

Our association believes that $5 million should be earmarked for cogeneration research. Gas-fired cogeneration technology can achieve better utilization of our energy resources by generating both electric power and heat to be used in industrial plants and commercial applications.

DOE's efforts should be aimed at helping industry achieve higher turbine life and ways to make industrial cogeneration systems more flexible to meet the needs of the potential market. Finally, INGAA supports $5 million for development and demonstration of natural gas fuel vehicles. The technological problems that remain to be solved mostly involve the storage of the gas in the engine performance.

The money contained in the DOE budget request falls well short for natural gas R&D programs. I urge this Subcommittee to increase the funding along the lines that we have suggested. Thank you, Mr. Chairman, for the opportunity to present my views.

[The prepared statement of Dr. Jones follows:]

STATEMENT OF VERNON T. JONES, CHAIRMAN
INTERSTATE NATURAL GAS ASSOCIATION OF AMERICA
BEFORE THE
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

MARCH 3, 1988

Madam Chairman and Members of the Subcommittee:

My name is Vernon Jones. I am President of The Williams Companies and Chairman of the Interstate Natural Gas Association of America (INGAA). I am appearing here today on behalf of INGAA's member companies to express our views on the FY89 Department of Energy (DOE) Research and Development (R&D) budget.

INGAA is a non-profit national trade association representing virtually all of the major interstate natural gas transmission companies operating in the United States. Our companies move natural gas from the producing areas to end users or distributors across the nation who, in turn, deliver the gas to the ultimate consumer. Approximately 90 percent of the natural gas transported and sold annually in interstate commerce flows through the more than 200,000 miles of pipeline owned and operated by INGAA's member companies.

The Importance of DOE's R&D to the Natural Gas Industry

Natural gas is an important national energy resource which is vital to our economic well being, environmental goals, and national security requirements.

Natural gas is predominately a domestic resource whose production, transmission, distribution and consumption helps generate jobs and enhance economic activity in most regions of the U.S. Moreover, because of its good economics, it helps American industry be more competitive at home and in overseas markets. The economics of natural gas as an energy source for most users in the U.S. are excellent because of its low resource cost plus the low cost of equipment to transform it into useful energy. In addition, the efficiency of natural gas equipment is typically higher than that of other fossil fuels, further improving its economics.

From an environmental point of view, natural gas is the cleanest fossil fuel in terms of its combustion characteristics and emissions. Natural gas delivered to the interstate pipeline system contains virtually no sulfuric compounds and, hence, does not contribute to sulfur oxides emissions (SO_x) that are among the primary causes of acid rain and other potential environmental and health hazards. In addition, gas combustion products contain significantly less nitrogen oxides (NO_x) compared to coal and fuel oils and contain no particulate matter such as that which forms in the combustion of most petroleum products and coal. Significantly, natural gas combustion in all applications does not result in any solid waste (ash or sludge) that has to be disposed of in a way that might adversely affect the environment.

The national security importance of natural gas has not always been fully appreciated. A number of factors combine to put natural gas in a position to help with security concerns.

- The U.S. proven conventional natural gas reserves can sustain current production levels for about 10 years. More importantly, there are additional vast potential reserves that can be tapped using current or advanced technologies to create a reserve base that can assure the availability of gas, at minimum, well into the next century;

- Natural gas can easily substitute for 80 to 90 percent of fuel oil currently used in electric utilities and industrial plants, and with additional distribution and/or transmission capacity natural gas can substitute for fuel oil in home heating applications in the Northeast and parts of the Southeast, thus reducing our imports of crude oil and exposure to supply disruptions and/or large price increases;

- The existing extensive transmission and distribution pipeline system (over a million miles long) represents one of the most efficient and safe ways to deliver energy to American homes and workplaces and, being mostly underground, is less vulnerable to sabotage or accidents compared to tanker, barge, rail, and truck transportation or above ground power lines; and
- The substantial natural gas resources of Canada represent an added supply security factor to U.S. consumers.

Thus, from an economic, environmental and national security perspective, it is imperative that this country maintain a healthy and viable natural gas industry, through continued R&D efforts to develop even higher efficiency and lower cost production, transmission, distribution, and end-use technologies.

INGAA Considers Continued Natural Gas R&D Crucial

The U.S. Department of Energy plays a vital role in assuring the continued availability of natural gas to U.S. consumers at competitive prices through the judicious use of government funds in areas that the private sector cannot or has difficulty addressing. Specifically, the DOE research and development budget should target technology problems that:

- Require long-term, technically high-risk/high-reward research projects that private companies would not include in their R&D budgets which are typically subject to market forces and focus on implementation and commercialization projects;
- Represent financially risky returns due to considerable uncertainties about future

energy prices and end-use demand; and

- Represent maximum national benefits to all consumers in terms of continued availability and stable prices of gaseous fuels produced domestically.

With these general guidelines in mind, we feel that DOE's R&D budget in areas related to natural gas should be enhanced to include special emphasis on:

- Projects supporting long-term production and transmission of pipeline-grade gaseous fuels from various sources and at competitive prices; and

- Exploring innovative and more efficient ways to use gaseous fuels in current and new applications that are consistent with our national goals of competitive economics, benign environmental impacts and secure supplies.

INGAA is aware and supportive of the research and development efforts of the Gas Research Institute (GRI). For a number of years, GRI has coordinated research directions and exchanged technical information with the DOE. The GRI program is focused, however, on near-term research because of, among other factors, budget limitation. Thus, DOE's role is critical to the gas industry not only on its own merits but also because of the support and enhancement it provides to private research organizations like GRI in public/private partnerships.

Taking these factors into consideration, INGAA recommends enhancing DOE's R&D budget items along the lines detailed below.

Specific Project Area Funding Recommendations

A summary of INGAA's recommended funding for DOE's Fossil R&D projects which relate to natural gas and gaseous fuels in FY89 is provided in the attached Exhibit 1. While the recommended budget figures are higher than those requested by DOE in the specific areas, they are generally less or equal to DOE's estimated budget for FY 1988. A brief discussion of the reasons behind the recommended funding levels is included here for each of the major program areas.

Unconventional Gas Recovery ($20 million)

Substantial amounts of natural gas have been identified in tight geological formations including the Eastern Devonian Shales (in the Appalachian, Michigan and Illinois basins) and Western Tight Sands. With resource estimates of up to 2,000 trillion cubic feet (Tcf) of gas in-place (roughly equivalent to 345 billion barrels of crude oil), an effective R&D program aimed at assessing the geoscience, geomechanical and geothermal factors influencing gas production from these formations and the productivity of various stimulation techniques could result in significant additional gas production by the turn of the century. Estimates of that additional production place it at about 4.0 Tcf (equivalent to about 2 million barrels/day of crude oil). The current technical knowledge and research are insufficient to attract private funds to start implementing effective unconventional gas production projects that would help the economies of many producing regions of the country as well as all natural gas consumers.

Surface Coal Gasification ($15 million)

Gasification of surface coal has the potential to provide up to 200 billion cubic feet (Bcf) of additional gas supplies (equivalent to 34 million barrels of crude oil) annually. This program requires additional funds in order to solve some of the remaining technical problems related to gasifying coal fines and liquid by-products. A major additional goal for the program should be the production of pipeline-grade gaseous fuel to allow for its transmission and use by all customers. However, even without reaching that goal in the mid-term, the impact of the current program is to extend the life of the natural gas resource base while allowing some customers to continue to use gas-based technologies (the Industrial Fuel

Gas Production program). Additionally, the Great Plains project is an important on-going project that offers an excellent opportunity to understand better the complex chemical, material and thermodynamic aspects of the gasification process at a full scale site.

Geopressured Research ($10.4 million)

This research has been focused on producing both gas and electricity from brine reservoirs with help from private sources (the Electric Power Research Institute). However, in the Texas and Louisiana gulf coast, geopressured brines contain vast amounts of methane (the main component of natural gas). Some estimates of the total resource place it at 100,000 Tcf, but only 25 to 1,200 Tcf of the gas might be recoverable. If innovative technological breakthroughs can be achieved, this resource could become a virtually unlimited source for natural gas.

The DOE research in this area should be accelerated and redirected to concentrate on ways to recover even a small fraction of the dissolved methane. DOE's efforts should attempt to maximize gas recovery and deemphasize electricity generation from the low grade heat in the brine reservoirs.

Biofuels Energy Systems ($8 million)

Deriving methane (the main component of natural gas) and liquid fuels from abundant organic agricultural crops and waste material is a sound economic, environmental and energy policy. The U.S. has ample land and marine resources to grow biomass that could be used to produce methane to supplement other natural gas supplies.

The recommended funding is aimed at continuing DOE's efforts in the areas of energy crop and energy conversion technology development. The efforts should continue to pursue promising genetic techniques to help increase the methane yield from the fermentation of various types of land and marine crops.

Underground Coal Gasification ($1.75 million)

The main objective of this program is to develop technically and economically viable technologies for *in situ* (i.e., underground without mining) conversion of coal to a clean, pipeline-grade gaseous fuel. The key advantages to this approach include:

- Improved utilization rate of the coal resource since 93 percent of U.S. coal cannot be recovered economically using conventional mining techniques.
- Reduced environmental and land-use impacts because of reduced mining and sludge production at the surface.
- Wider usability of the coal resource when transformed into pipeline-quality gas that can be moved and burned more easily than coal.

In spite of all the research to date, DOE's efforts still have to complete extensive field testing to understand better the process and any potential environmental impacts on surface or underground water.

Liquid Spill Test Facility ($1.5 million)

The recommended funding for this facility is aimed at enabling DOE to continue to operate and maintain the Nevada site where private and government researchers test the impacts of various liquid spills. The importance of this facility to the natural gas industry is in understanding the impacts of liquefied natural gas (LNG) which is the only means for importing additional supplies of natural gas from overseas. The test facility helps the industry conduct research of such questions as the advantages of underground storage, behavior of spills on different surfaces, and for evaluating different spill prevention methods.

Conservation ($24 million)

For presentation purposes, several of DOE's programs to improve the efficiency of energy utilization and diversify the fuel choice options for U.S. consumers are grouped under this heading. Since conservation and fuel option diversification help extend the life of domestic energy resources, INGAA recommends a FY89 funding of $24 million in the following areas:

- Gas heat pumps
- Industrial cogeneration
- Industrial heat pumps
- Indoor air quality
- Building materials
- Building subsystem interactions
- High-temperature recuperators
- Energy Conversion and Utilization Technologies

Gas Heat Pumps ($7 million)

Utilizing the thermodynamic cycle of a heat pump, a gas-based system can achieve efficiencies of 25 to 50 percent higher than gas furnaces when used for heating indoor space. More research is needed to develop more efficient and reliable gas heat pumps that offer both space heating and cooling. The research would focus on advanced materials and designs for the gas engine and the compressor as well as research of various types of thermodynamic cycles to achieve the cooling effects.

Industrial Cogeneration ($5 million)

This technology can achieve much better utilization of our energy resources by generating both electric power and useful heat to be used in industrial plants as compared to generating electricity only at power plants and useful heat at industrial sites. Gas-fired cogeneration technologies are the best available means for capitalizing on the benefits of cogeneration. DOE's efforts should be aimed at helping industry achieve higher turbine life and efficiency to improve the overall productivity of the system. Another important goal should be exploring ways to make industrial cogeneration systems more flexible in their output mix (between electricity and heat) to accommodate the fluctuating needs of most industrial plants.

Fuel Cells ($22.7 million)

This technology holds a lot of promise to improve the efficiency of converting fossil fuels to electricity and useful heat. Advanced concept gas fuel cells, in particular, are 30 to 40 percent more efficient than today's conventional combustion-based electricity generation methods at power plants. This is achieved because fuel cells utilize an electrochemical process of generating electricity and useful heat from natural gas without the inherently less efficient combustion process. In addition, fuel cells do not generate any combustion emissions (they generate electricity, heat, and water) and, thus, are benign environmentally except for possible leaks of the electrolytic material.

INGAA supports the current technological goals and objectives of the fuel cells program, but strongly recommends that DOE consider all feasible and economic fossil fuels as options to operate the cells. Natural gas, in particular, should be considered along with coal which is the focus of the current program. In addition, INGAA supports the development of second generation molten carbonate fuel cells which are more suitable for industrial applications, and direct conversion concepts such as the solid oxide cell.

Advanced Research and Technology Development ($6 million)

This program area provides fundamental research that underlie the development of all fossil energy technologies. It includes high-risk, high-return generic research that addresses basic materials requirements, thermochemical processes and advanced instrumentation concepts. The recommended funding would allow DOE to continue its coal gasification research, developing low-cost gas cleanup processes and low-cost synthesized gas production.

DOE's efforts here should also continue in the areas of better understanding of erosion, corrosion, and the wear and thermal properties of ceramic materials, to help energy technologies in the industrial sector in particular.

Natural Gas Vehicles ($5 million)

INGAA supports development and demonstration of natural gas vehicles. Natural gas may be able to play a significant role in reducing crude oil imports through technological breakthroughs which might be achieved in this program. The technological problems that remain to be solved are mostly in the natural gas storage and engine performance areas.

Conclusion

The funding recommendations discussed here target programs that represent the true mission of DOE in energy R&D in general and natural gas research in particular. In an era of budget constraints, government funds should be focused in high-risk, high-reward, widely applicable research that the private sector cannot undertake unassisted. The recommended funding is designed to help achieve technological advancements so that natural gas can achieve its potential and play an even more significant role in advancing our nation's economic well being, clean environment, and secure energy supplies.

EXHIBIT 1

REQUESTED AND RECOMMENDED FY 1989 FUNDING FOR FOSSIL ENERGY R&D IN GAS-RELATED AREAS

(In Million Dollars)

Program Area	DOE Request	Industry Recommendation
• Supply and Transmission:		
- Unconventional Gas Recovery	$ 1.73	$ 20.00
- Surface Coal Gasification	5.03	15.00
- Geopressured Research	2.90	10.40
- Biofuels Energy Systems	4.30	8.00
- Underground Coal Gasification	0.27	1.75
- Liquid Spill Test Facility	0.77	1.50
• End-use Technology:		
- Conservation	7.50	24.00
- Fuel Cells	6.63	22.70
- Advanced Research & Technology Development	5.10	6.00
- Natural Gas Vehicles	0.00	5.00
Total	$34.23	$114.35

PANEL 4 DISCUSSION

Mr. **Chapman**. Thank you, Dr. Jones, and my thanks to the entire panel. Let me start back, Mr. Baly, with this question. In your testimony you talk in terms of foreseeable technological breakthroughs and so on, that there is a 50-year supply of recoverable natural gas in the lower 48.

One of the things that I think perhaps many people in this country have come to believe that that would seem to refute, is that we should move to other energy sources for the reason that we will run out of natural gas more quickly than any other energy supply.

Do you foresee, and in your opinion—I ask this of the rest of the panel as well—do we have those kinds of supplies that can be recovered under technologies that can be developed in the relatively new term?

Mr. **Baly**. Yes, sir, Mr. Chairman. Supply is not the problem today, demand is the problem. If we can't go out and find ways to replace imported oil with natural gas, that will not stimulate the drilling to go out and use the technological advances that we need to see in Texas, Oklahoma and elsewhere to get out the kinds of resources that we are talking about.

DOE, which has been very conservative in years past, we have come before you and complained about their energy triad of nuclear, coal and conservation. They declared in a recent study there are 200 years of natural gas. If you can get out the geopressured methane and other sources that we are talking about this morning, you could be describing thousands of years of natural gas.

Clearly, in testifying on the free trade agreement this week, we mentioned that by the year 2010, 90 to 95 percent of the gas will be domestic. We are talking about demand projections of going from 17 trillion cubic feet today to an upside of 27 trillion cubic feet. So we are looking at domestic production, 90 to 95 percent of a much larger pie. A potential of 27 trillion cubic feet the energy mix that gas had in the 1960's.

So the answer is yes, we have the supply. As demand increases, we move those kinds of gas that we could not get back into our proven and potential reserves.

Mr. **Chapman**. Let me, from those comments, move to perhaps another leg of a national energy policy stool and ask you if supply is not the problem but it is demand, I would presume that price of natural gas which tracks the price of oil for reasons sometimes I find a little mysterious. But nonetheless, it does.

Is a component of this—and I don't want to get off of the research end of the purpose of this hearing—a component of what we are about here today would probably be a price for gas that justifies exploration as well as research and development; is that a fair statement?

Mr. **Baly**. As natural gas competes in more of an upscale market, the new high-tech combined cycle electric generation and other advanced uses, we don't see natural gas necessarily tracking oil particularly if it should increase under the threat of OPEC or whatever.

We are not convinced that natural gas would follow that higher trajectory.

Dr. Lee. If I may add a comment, I totally agree with what Mike said, but I think we don't have any resource problem. But a resource that cannot be made available through technology is pretty useless. So I think the need to continue technology development to make those resources available in a time that they are needed is absolutely essential.

Mr. Chapman. That's sort of like being the noon hour and we know there's a pizza out there at the pizza place, but it's not here. Until we can figure out how to get it here, it does us very little good.

Dr. Jones. Mr. Chairman, may I offer a couple of comments?

Mr. Chapman. Surely.

Dr. Jones. I quickly would say that currently the reason that gas prices track with oil prices is because about six TCF out of a 17 TCF market have installed alternative fuel capability. Mr. Morrison's market in particular, residual and natural gas, go head-to-head on all the industrial market up there essentially. That is basically the reason they would track.

Whether they would decouple if you arrived at a point in time where there were gas shortages for whatever reason available, to the U.S. market is a matter of conjecture. But I think that is the distinct possibility.

With respect to the timing of the highly-technical R&D that is a part of what is being advocated here with this panel, I think the timing is now. While clearly there are available supplies that comfortably get us well into the next decade at the very least and perhaps even beyond that, the development and application of the kind of technologies that we are talking about here take time.

Certainly a large component of the private sector cannot do it without Government funding. The returns are there, they are extremely significant not only from an economic but also from a national security standpoint. The time to get on with that research is now, so that those technologies can be brought on in a timely fashion.

Mr. Chapman. Let me ask just a couple of more questions and then turn it over to my colleagues. A recommendation of $1.75 million to continue the underground coal gasification project for next fiscal year, from information we have, the Department of Energy has spent over $100 million on this since 1977.

Can one of you comment on when we will complete this project, if ever, and how much it is going to cost before we finally finish it? How much more?

Mr. Webb. Mr. Chairman, let me comment. I do not have the background on those total numbers, but the program that we are talking about, we are currently in a 100-day burn. When I say we, we have an industrial consortium in GRI and we are putting up about 60 percent of the funds with DOE in the burn in Wyoming.

The results of that burn, we will need to analyze. What we are proposing with this additional money for 1989, is to continue to develop the database. One of the Clean Coal Technology proposals that I believe is under contract negotiations, is to build a commercial-scaled facility to take medium BTU gas produced from underground coal gasification to produce ammonia.

So we are talking about only a couple of more years to get the baseline so that they can properly design and go forward with this Clean Coal Technology Program where industry is putting up significant millions of dollars to build a facility. What we are talking about doing is giving them the engineering database so they can design that plant to be as efficient as possible.

Also, industry is putting up like I say, more than half the money in this coal gasification work out in Wyoming with the Department of Energy.

Mr. CHAPMAN. Are any of you specifically familiar with the multi-well experiment, and if so, has it been beneficial?

Mr. WEBB. Yes, sir, Mr. Chairman. We have been involved in that program with DOE and where we are not directly cofunding it, we are coordinating with it. We do meet with them twice a year to go over the program. It has been very beneficial, and we have transferred some of that technology to the work we are trying to do at the Bureau of Economic Geology down in some of the tight sand formations in Texas and New Mexico.

We think that program should be continued. What we actually have there is a laboratory in the field to conduct some experiments in directional drilling, some experiments in techniques to fracture formations and try to get more resource out of these very tight formations.

Through this latch up we have and we have program symposiums a couple of times a year, we are about to transfer the technology to GRI, and we in turn, transfer it through our member companies and the people participating in our programs to the industry.

I certainly recommend that we continue that for another year or two to get all the information that we can. We have invested about $20 million in the facility. We ought to go ahead then and get as much data as possible out of it.

Mr. CHAPMAN. Thank you. Mr. Morrison.

Mr. MORRISON. Thank you, Mr. Chairman. Gentlemen, obviously you represent a most significant industry, and I agree with you in the role of natural gas in the future energy mix of this country. Dr. Jones, we are delighted with your role in the Pacific Northwest. We love the energy you bring to us.

I have one basic question, having gone through this now for two years. What is the reasoning within the Department of Energy why they take what seems to be programs that are making dramatic progress and just cut the very heart out of them? Do they sense that your technologies are developed far enough that we need to make that sometimes painful shift to private enterprise? What do you sense is their reasoning?

Mr. WEBB. Congressman Morrison, if I could respond. My sense is that if you have a project where you've got good industrial participation and it's making progress, if OMB deletes that out of the budget then individuals and institutions such as us will up here today before you making the case to have it restored.

I think it strictly is a matter of when they essentially have the OMB going by some arbitrary number on how much research should be funded, and obviously conservation, fossil and renewable energy always takes the largest cuts from the OMB passbacks to the Department.

They tend to cut out what is referred to in the trade as the gold watches. The gold watches of those projects are making progress where you have industrial participants. In our case you have probably 50/50 cofunding under the assumption that Congress will probably put those back in the budget. They won't be as devastating as it first looks when they send the budget up. That's my personal opinion of what goes on, sir.

Mr. MORRISON. That is rather fascinating. In other words, the best projects, the ones that are making the most progress for the country are going to be supported universally up here and so we will plug them back in.

Mr. WEBB. Yes, sir. That's been my observation.

Mr. MORRISON. I would have to say that maybe history would prove that to be right. It is unfortunate that the natural energy policy is driven in that way.

Dr. LEE. If I may make an observation, my thought is that there is a philosophical difference in emphasis. The Administration continues to place great emphasis on nuclear research in tough times or good times.

For some reason, fossil energy resource and technology development is considered to be something that the free market and industry would take care of if Government steps aside. That perception and that concept, we believe is what causes the year-by-year reduction of budget.

The emphasis lately has been on very fundamental research, which is very important. But somewhere missing between the fundamentals and the marketplace is a long chain of R&D which the free market or the private industry is not in a position to handle. It is a length of time that is needed to develop technology that is not being adequately recognized, in my judgment, in the fossil field.

That sort of understanding is appreciated in the nuclear or fusion, realizing long-term support, but the fossil is not being looked at properly.

Mr. BALY. I think, Mr. Morrison, we have had a difficult time getting them to understand that particularly the gas research is not like a water tap that you can turn off and on. If we are going to be able to keep moving with industry cooperation, you are going to have to have a coherent, stable direction. I agree with Mr. Lee. They seem to see that in the electric area, whether it's a $6 billion nuclear proton reactor.

Whether it's the fact that DOE came out of the old Atomic Energy Commission, fossil has been the tail on the dog.

Mr. MORRISON. I, as one, am a firm believer in the industry participation and also sense that the only way we get it is to provide a strong element of consistency so that you know we are going to continue to be your partners.

However, you do reach a certain point where obviously it moves to your hands. I sense in the programs that you have emphasized, the most in your testimony are the ones that aren't there yet. I think you are going to find some support.

Mr. Chairman, thank you for the opportunity to speak with these gentlemen.

Mr. CHAPMAN. Thank you, Mr. Morrison. Does the gentleman from Connecticut have questions?

Mr. SHAYS. I have no questions, Mr. Chairman.

Mr. CHAPMAN. Gentlemen, let me just conclude with a couple of questions, if I may. Dr. Lee, there is some information apparently from some source, I know that is of some concern to the Committee, about that Hulin Well in Louisiana.

I notice that your statement describes perhaps a rework effort there. Some indication is, perhaps, that well may be dangerous in its current condition. Do you have any idea what kind of money it is going to take to do what needs to be done there as to that specific property?

Dr. LEE. The exact dollars I don't have, but I think it is in the order of $3 million. The program that we suggested, $10.4 million takes care of three wells. I am more familiar personally with the Pleasant Bayou, having just visited that recently. All the structure above ground is in place ready to do the experiment work. The Gladys McCall is being run well to gather data. Hulin is precisely the one that you are mentioning, needs additional rework to make sure that the brine can be disposed of in an environmentally acceptable manner.

Mr. CHAPMAN. Is there any work going on at Hulin now?

Dr. LEE. I am not aware of it. Some work is going on, to what extent I don't have. But I would be happy to supply the precise data for your file.

Mr. CHAPMAN. That might be something that the Committee should actually target and focus on, just to make sure that there is adequate funding, if in fact, there's an environmental or safety problem there to make sure that is addressed.

Dr. LEE. I will be happy to supply that for you, sir.

[The information follows:]

ANSWER TO QUESTION FOR DR. BERNARD S. LEE ON GEOPRESSURED WELL

The Willis Hulin Well, in Vermillion Parish, Louisiana was drilled to 21,546 feet by Superior Oil Company in 1979. Superior began gas production and sales in September 1981 from thin shaly sand zones at a depth of about 21,100 feet. Production ceased in April 1983 because of pressure decline, leading to water and condensate blocking the bottom section of the well. Because the well contains several geopressured geothermal reservoirs, Superior offered to donate the well to DOE's Geopressured Geothermal Research Program, and DOE accepted. Since DOE took over ownership of the well in early 1984, program funding has allowed only the monitoring of pressures in the annuli of the well, and the payment of insurance and lease expenses. Weekly checks of pressure in the annuli show that the pressures are increasing.

We are concerned that if pressures are allowed to continue to increase, internal damage to the well could result, greatly increasing the cost and risk of entering the well to correct the problem. If the pressure buildup is ignored, the well could ultimately blow out. Because the well is located approximately three miles from Vermillion Bay, a blowout would result in salt water damage to farmland immediately adjacent to the well and contamination of surface water and ground water flowing into Vermillion Bay. In addition to environmental damage, the cost of controlling a well that has blown out is much greater than a normal workover of a well. With time, the mud in the well will continue to deteriorate and any plugs already present from mud consolidation will become thicker, further aggravating the difficulty of workover. Consequently, a successful cleanout operation will become more difficult and expensive to achieve the longer the well is left dormant. The Hulin well must be cleaned out before either recompletion or a plugging and abandonment operation.

The DOE decision to acquire the Hulin well in 1984 was based on the intent to use the Hulin well as a design test well. The reasons for testing the Hulin well are still valid today. A long-term production test of the Hulin well would be of particular value and interest to industry because previous DOE geopressured well tests have all been from reservoirs in the 12,000 to 15,500 foot depth range. Test data from 20,000 feet would allow industry to evaluate the increased energy recovery versus higher drilling costs at the greater depth.

Of the $10.4 million we are suggesting for the Geopressured program, $3.0 million would be used to clean out the Hulin well.

Mr. **Chapman**. Gentlemen, I think for the sake of time, there are other questions I would love to ask and with your permission we might submit and request answers in writing.

Let me just say again how much I appreciate your coming here. Let me say something else. I don't know how you gentlemen do it, but before this Committee, you are organized and you obviously thought out ahead of time what the priorities within the research budget of your business ought to be.

I don't know whether you get together and flip a coin ahead of time to decide what numbers ought to go in these various slots, or how that process is worked out. Let me say that it is refreshing that you have thought through the industry and the problems of the industry, where we ought to be going and presenting a united front on what we ought to be doing as far as the Federal R&D effort is concerned.

I applaud the work that you do. I hope that once more, we will be able to change these numbers, however they get here, to more accurately reflect what our priorities ought to be. I thank you each for appearing before us today.

This Committee will stand in recess.

[Questions and answers for the record for Panel 4 follow:]

GRI
gas research institute

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202/662-8935

DAVID O. WEBB
Senior Vice President,
Policy and Regulatory Affairs

April 14, 1988

The Honorable Marilyn Lloyd, Chairman
Subcommittee on Energy Research & Development
Committee on Science, Space, and Technology
U.S. House of Representatives
B-374 Rayburn House Office Building
Washington, DC 20515

Dear Madam Chairman:

Attached are the answers to questions from your March 3 hearing on fossil energy R&D. I appreciated the opportunity to appear before your Subcommittee to discuss the gas industry's recommendation for a more balanced energy R&D program. Gas Research Institute thinks gas has an important role in providing an abundant, clean energy source for this nation's energy security. A balanced R&D partnership between the gas industry and the Department of Energy can ensure a stable, constant supply.

If you desire further information on any of these questions, please let me know. I will be happy to provide it for you.

Sincerely,

David O. Webb
David O. Webb

Attachment

Gas Research Institute, 8600 West Bryn Mawr Avenue, Chicago, Illinois 60631 312/399-8100

1. **What is the current demand for natural gas in the United States? What is the current supply? How long do you expect domestic natural gas supplies to exceed demand?**

According to the 1987 GRI Baseline Projection of U.S. Energy Supply and Demand, the actual 1986 consumption of natural gas was 16.5 quads. The outyear projections are for 17.1 quads in 1990, 18.5 quads in 2000, and 18.9 quads in 2010.

The 1987 Baseline also indicates that in the long term future gas supplies are adequate to meet projected demand. The projection indicates that even at low wellhead gas prices the drilling activity necessary to provide the required production is economically justifiable. However, since early 1986, there has been a record decline in drilling activity. This record decline has led to serious concerns about the near-term outlook.

The U.S. natural gas resource base is extremely large, especially when the unconventional resources such as tight gas sands, Devonian shale, and coal seams are included. GRI estimates that approximately 700 Tcf of gas reserves (a 40- to 50-year supply at current consumption rates) are yet to be discovered and produced in the U.S.

The current decline in drilling activity and the gradual recovery in gas demand witnessed in 1987 indicate the "gas bubble" will dissipate within the next two to three years. As gas supply and demand come into balance, the inevitable result will be an increase in the price of gas at the wellhead. The price increase will stimulate drilling activity.

The recent Department of Energy advance summary of oil and natural gas reserves[1] shows that despite the severe decline in gas well completions, lower-48 natural gas reserve additions were 14.7 Tcf, 96 percent of lower-48 production. Annual lower-48 gas supply could remain adequate through about 1991 at the current low level of reserve additions. However, the gas industry will have to rely increasingly on storage withdrawals to meet winter demands toward the end of the decade, but these should not exceed normal rates unless the winter is excessively cold.

It's important to note that the unconventional gas research program GRI is funding as well as the budget recommendations GRI made for DOE's unconventional gas program are focused on unconventional gas resources. These resources are the keys to long-term, assured supplies of gas for the U.S.; therefore, there is a need for a federally funded program.

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[1] U.S. Department of Energy, Energy Information Administration, "Advance Summary U.S. Crude Oil, Natural Gas, and Natural Gas Liquids Reserves," 1986 Annual Report (DOE/EIA-0216(86)).

2. **DOE Secretary Herrington recently announced a major new study to perform a comprehensive assessment of the U.S. natural gas reserve potential. Why is such a study needed at this time?**

A study to assess the U.S. natural gas resource base is needed because currently there is disagreement among several institutions regarding the size of the U.S. natural gas resource base. If natural gas is to meet its true potential in helping to reduce the level of oil imports by expanding gas use in the industrial and utility sectors, there needs to be a consensus regarding the adequacy of the gas resource base. Before industry executives will invest capital in building new facilities to use gas instead of imported oil, they must have assurances that the gas resource base is sufficient to supply their plants for at least the next 25 years.

The DOE Natural Gas Initiative, therefore, is one critical step in reducing oil imports by expanding natural gas use.

3. **What funding level does the gas industry recommend for phosphoric acid fuel cells?**

While the 40 kW onsite fuel cell contract between International Fuel Cells and the Department of Energy has been completed, there is still critical research that needs to be conducted to advance the technology and reduce the costs. In a recent assessment of research needs made by DOE's Office of Energy Research, numerous technology areas were delineated which warrant either continued research or initial probing. These include the following:

A. Power Section

The power section is the generating source of direct current via a dynamic electrochemical process. This section uses expensive components which are unique to fuel cells but have the potential for both cost reduction and higher power density as manufacturing processes evolve. As a subsystem, this represents the most expensive part of a fuel cell. Improvements are continually made in catalyst structure and activity that will require less expensive platinum, operate at higher temperature/pressure, and have improved kinetics; the latter explicitly addresses critical cell efficiency issues. Research is also showing that the electrolyte can be modified to increase conductivity at higher temperatures that are needed to achieve greater throughput. Both electrolyte and matrix structures are being altered to minimize corrosion, maintain seals, minimize cross-over, and improve overall electrolyte management, which would have the net effect of a longer power plant (stack) life.

B. Fuel Processing Section

Due to the large volume of fuels, either gas or liquids, required to generate the direct current, this subsystem represents a high cost in equipment/materials. Although technology exists from petrochemical industries to process these fuels, a unique and severe constraint is placed in fuel cell power plants from the viewpoint of system volume, footprint, thermal management, impurities and overall integration. A critical need exists to extend the catalyst tolerance to impurities and to increase its strength, thermal transfer, and efficiency of chemical conversion while maximizing throughputs. Concepts for achieving the above normally evolve from the fuel cell developers, rather than the chemical industries. The developers are suggesting new configurations that reduce redundancy and remove or combine certain process steps that will provide a lower overall system cost.

C. Power Conditioning Section

The power conditioning section is critical for providing electricity (AC) in a form that is completely compatible with the present electrical service. High-power inverters have been developed over the years primarily to accommodate variable-speed motor-generated AC quality or for high-voltage DC transmission service. A more recent semi-commercial effort has been devoted solely to AC from battery or other pure DC sources that have no residual ripple. Solid state devices (transistors, gate turnoff, etc.) are slowly being developed and scaled up; they will provide a constant high-purity AC signal at high conversion efficiencies (about 96 percent). In parallel with this solid state materials development, circuitry/logic boards are also required to provide the fine control needed to achieve the high conversion efficiency. An added benefit of these advancements is the improved safety and reduced cooling requirements of the total power conditioning system.

D. Ancillary Systems

The need exists to find cures for unique corrosion/flow/volume/temperature control problems due to the close physical integration of components and concurrent chemical/electrical processes. When the required controls are found, users will experience much greater reliability, reduced maintenance frequency/cost, and higher acceptability of the PAFC technology.

The attached table outlines the impact in both cost and technology which could be achieved through continued research. GRI recommends a $5 million program in advanced generic research in phosphoric acid fuel cells.

Attachment

TABLE 1

IMPACT OF RESEARCH ON PHOSPHORIC ACID FUEL CELL TECHNOLOGY

Research Area	Potential Benefit*
Power Section:	$200/kW cost reduction 800 Btu/kWh heat rate reduction
• Catalyst Improvement/Reduction	
• Electrolyte Modification	
• Electrolyte and Matrix Structure	
• Cell Component Modification	
Fuel Processing:	$100/kW cost reduction Reduced maintenance cost $5 to 10/kW yr 200 Btu/kWh heat rate reduction
• Catalyst Modification for:	
- Improved Impurity Tolerance	
- Improved Strength and Heat Transfer	
- Increased Throughput	
• System Reconfiguration	
• Higher Temperature Reformer Materials	
Power Conditioning Requires:	$40/kW cost reduction 100 Btu/kWh heat rate reduction
• Electronics Advancements	
• Improved Logic	
Ancillary Systems:	$50/kW cost reduction Reduced maintenance cost $5/kW yr 300 Btu/kWh heat rate reduction
• Tolerant Materials	
• Corrosion Abatement	
• Improved Controls/Sensors	
• Decreased Coolant Maintenance	
• Component Reliability	

* Projections from ongoing research.

SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT

Hearing on the Department of Energy (DOE)
FY 1989 Authorization Request for Fossil Energy

Republican Member Questions for the Record
for the Hearing of March 3, 1988, for
BERNARD S. LEE

IMHEX Molten Carbonate Fuel Cell Stack Program

1. What level of funding in FY 1988 is DOE providing to IGT for the IMHEX Molten Carbonate Fuel Cell Stack Program.
2. What IGT funding is being applied to the Program in FY 1988?
3. What prior-year funding has (a) DOE and (b) IGT supplied to the Program?
4. Please identify a Program completion date and the funding required to reach program completion.

Contaminant Resistant and Endurance Related Issues

1. What level of funding in FY 1988 is DOE providing to IGT for the research on contaminant resistant and endurance related issues of molten carbonate fuel cells?
2. What IGT funding is being applied to these particular research efforts in FY 1988?
3. What prior-year funding has (a) DOE and (b) IGT supplied to these particular research efforts?
4. Please identify a completion date and the funding required to reach completion of these efforts.

Advanced Alternate Planar Geometry Solid Oxide Fuel Cells (SOFC)

1. What level of funding in FY 1988 is DOE providing to IGT for the R&D work on a novel planar SOFC concept?
2. What IGT funding is being applied to this concept in FY 1988?
3. What prior-year funding has (a) DOE and (b) IGT supplied to this concept?
4. Please identify a completion date for the concept and the funding required to reach program completion.
5. What is the relationship between IGT and Ceramatec?

Solid State Proton Conductors (SSPC) Fuel Cells

1. What level of funding in FY 1988 is DOE providing to IGT for the SSPC fuel cells?
2. What IGT funding is being applied to SSPC fuel cells in FY 1988?
3. What prior-year funding has (a) DOE and (b) IGT supplied to SSPC fuel cells?
4. Please identify a SSPC fuel cell program completion date and the funding required to reach program completion.

Development of an Advanced Mild Gasification Process

1. What level of funding in FY 1988 is DOE providing to IGT for the development of an advanced mild gasification process?
2. What IGT funding is being applied to the process in FY 1988?
3. What prior-year funding has (a) DOE and (b) IGT supplied to the process development?
4. Please identify a process development completion date and the funding required to reach completion.

Development of the TADCO Coal Gasification Process

1. What level of funding in FY 1988 is DOE providing to IGT for the development of the TADCO Coal Gasification Process?
2. What IGT funding is being applied to the Process in FY 1988?
3. What prior-year funding has (a) DOE and (b) IGT supplied to the Process?
4. Please identify a Process completion date and the funding required to reach completion.

Extending Pressurized Operation of Ash Agglomerating Gasification

1. What level of funding in FY 1988 is DOE providing to IGT for research on extending pressurized operation of ash agglomerating gasification?
2. What IGT funding is being applied to this research in FY 1988?
3. What prior-year funding has (a) DOE and (b) IGT supplied to this research?

Advanced Two Stage Coal Combustor (ATCCO)

1. What level of funding in FY 1988 is DOE providing to IGT for the ATCCO?
2. What IGT funding is being applied to the ATCCO in FY 1988?
3. What prior-year funding has (a) DOE and (b) IGT supplied to the ATCCO?
4. Please identify an ATCCO completion date and the funding required to reach completion.

Development of Hyperabsorption Cycle Heat Pump

1. What level of funding in FY 1988 is DOE providing to IGT for the development of the Hyperabsorption Cycle heat pump?
2. What IGT funding is being applied to this heat pump in FY 1988?
3. What prior-year funding has (a) DOE and (b) IGT supplied to this heat pump?
4. Please identify a completion date for this heat pump and the funding required to reach program completion.

Pressurized Gasification of Refuse Derived Fuels

1. What level of funding in FY 1988 is DOE providing to IGT for the RENUGAS process?
2. What IGT funding is being applied to the RENUGAS process in FY 1988?
3. What prior-year funding has (a) DOE and (b) IGT supplied to the RENUGAS process?
4. Please identify a RENUGAS process completion date and the funding required to reach process completion.

Enhanced Gas Storage for Vehicular Use

1. What level of funding in FY 1988 is DOE providing to IGT for the VE-GAS adsorption system?
2. What IGT funding is being applied to the system in FY 1988?
3. What prior-year funding has (a) DOE and (b) IGT supplied to the system?
4. Please identify a system completion date and the funding required to reach system completion.

Republican Member Questions for the Record
for the Hearing of March 3, 1988, for
Bernard S. Lee

IMHEX Molten Carbonate Fuel Cell Stack Program

1. Under the signed 2 year contract DOE has provided an initial sum of $4.7 million to be followed by additional funding increments.

2. Under the provisions of the contract IGT is to provide no cost sharing in FY'88.

3. No prior year funding was provided by either DOE or IGT for the IMHEX cost shared contract given that the contract was signed on February 24, 1988.

4. Under the provisions of the DOE contract the term of the effort is for two years, beginning February 24, 1988, ending February 24, 1990. Present federal funding is $9.4 million.

Contaminant Resistant and Endurance Related Issues

1. $1.044 million, including contaminant resistant and several endurance related contracts.

2. Under provisions of the contract no funding from IGT is required.

3. DOE provided $942.1K in FY'87 and $1.1 million prior to FY'87. IGT contributed most of the research equipment over the years.

4. This research would parallel the 5-7 year molten carbonate fuel cell development effort. Results of the contaminant resistant and endurance efforts will be generically integrated with the molten carbonate fuel cell.

Advanced Alternate Planar Geometry Solid Oxide Fuel Cells (SOFC)

1. DOE is providing approximately $25K in FY'88.

2. IGT has agreed to cost-share approximately $40K in FY'88 for construction of testing facilities.

3. None. IGT has performed preliminary research in-house.

Advanced Alternate Planar Geometry SOFC cont.

4. In the beginning stages of a research program, it is not feasible to predict either the completion date or the funding level.

5. Ceramatec is a completely separate materials company located in Salt Lake City, Utah. We have a teaming agreement and non-disclosure agreements for this project.

Solid State Proton Conductor (SSPC) Fuel Cells

1. DOE is providing approximately $25K in FY'88.

2. IGT is contributing approximately $21K for construction of a test stand to measure the protonic and electronic conductivity of the fuel cell electrolyte.

3. IGT has done in-house research in the amount of approximately $10K in prior years on this concept.

4. In the beginning stages of a research program it is not feasible to predict either the completion date or the funding level.

Development of an Advanced Mild Gasification Process

1. DOE is providing $665K in FY'88, as obligated under the current contract.

2. None.

3. DOE provided $137K in FY'87. IGT, none.

4. $2.2 million will take us to completion of the current contract in September of 1990.

Development of the TADCO Coal Gasification Process

1. None.

2. None.

3. None.

4. The suggested project would require $2.0 million over 3 years, taking us to the bench scale, and would be co-funded with Gas Research Institute.

Extending Pressurized Operation of Ash Agglomerating Gasification

1. DOE is funding related work in FY'88 for $180K.

2. IGT is providing $100K in FY'88 for data analysis.

3. DOE has supplied no prior year funding. The IGT family has contributed $500K. The Gas Research Institute has supplied $1.9 million in prior years.

Advanced Two Stage Coal Combustor (ATCCO)

1. None.

2. None.

3. None.

4. This proposed program would require $5.0 million over 3 years to go through the pilot plant stage, if started today.

Development of Hyperabsorption Cycle Heat Pump

1. None.

2. IGT is contributing $20K in FY'88.

3. DOE has provided no funding in prior years, IGT has contributed approximately $5K in research leading to this concept.

4. The $1.5 million program proposed by IGT would support the development of a proof-of-concept unit in 3 years.

Pressurized Gasification of Refuse Derived Fuels

1. None.

2. None.

3. DOE has funded RENUGAS technology development in prior years at approximately $4.4 million. IGT has provided $177K for an existing unfunded contract.

4. $1.0 million is needed for 1 year to complete process development unit testing using refuse derived fuel feed.

Enhanced Gas Storage for Vehicular Use

1. None.

2. IGT contributed $200K for FY'88.

3. DOE has supplied no prior year funds. IGT has provided $600K.

4. The $1.6 million in FY'89 would be used to scale up the storage system for larger, heavy-duty vehicle fleets. The success of this scale up is dependent on the results of smaller vehicle fleet performance currently under study.

SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT

Hearing on the Department of Energy (DOE)
FY 1989 Authorization Request for Fossil Energy

Republican Member Questions for the Record
for the Hearing of March 3, 1988, for
VERNON JONES, INTERSTATE NATURAL GAS ASSOCIATION OF AMERICA

1. What is the current demand for natural gas in the U.S.? What is the current supply? How long do you expect domestic natural gas supplies to exceed demand?
2. DOE Secretary Herrington recently announced a major new study to perform a comprehensive assessment of the U.S. natural gas reserve potential. Why is such a study needed at this time?
3. What funding level does the gas industry recommend for phosphoric acid fuel cells?

RESPONSE TO QUESTIONS FROM:
MARILYN LLOYD, CHAIRMAN
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

Q1: What is the current demand for natural gas in the U.S.? What is the current supply? How long do you expect domestic natural gas supplies to exceed demand?

A1: According to the Energy Information Administration (EIA), U.S. Department of Energy, total **consumption** of natural gas in 1987 was about 16.7 trillion cubic feet (tcf) of dry natural gas. Under today's competitive natural gas market, **demand** would generally be equal to **consumption** with the exception of demand by customers who did not have access to natural gas.

The EIA reports that domestic dry gas field **production** in 1987 was 16.3 tcf and net imports were about 0.9 tcf for a total of about 17.2 tcf supplied. About 0.5 tcf supplied but not consumed represent net additions to storage and unaccounted for quantities.

Natural gas field **production**, however, does not represent all potential **supplies** of natural gas since some domestic wells were not producing at maximum delivery capacity because consumption was less than capacity and for other reasons. This excess deliverability has been estimated by the EIA to be about 3.5 tcf in 1987. The outlook for this imbalance between domestic natural gas maximum delivery capacity and consumption is subject to a number of factors, the most significant two are:

- Growth in end-use demand; and

- Discoveries of new natural gas reserves.

Growth in end-use demand is subject to a number of factors that have caused significant change in its level during the past decade. Economic recessions, competition with fuel oils in the electric utility and industrial markets, conservation, new end-use technology penetration, and weather conditions are among the factors that have contributed to the 12 percent drop in domestic natural gas consumption between 1977 and 1987. There are indications that this declining trend is likely to be reversed because of such changes as:

- Renewed growth in the output of manufacturing industries driven by strengthened export markets which could lead to more natural gas demand;

- Increased use of natural gas in existing and new power generation applications because of its clean burning characteristics; and

- Increased interest in economical, smaller scale new natural gas-fired power generation equipment (such as combined-cycle units) which are very competitive in meeting the need for less capital intensive increments of power generation capacity.

Discoveries of new natural gas reserves have been less than production for seven of the past eight years. That means that the natural gas industry is not replacing all the natural gas that is produced and consumed. The slow down in drilling activity resulted from the gas surplus as well as from low crude oil and natural gas prices.

Those two trends, increasing end-use demand and lack of replacement of produced gas indicate that the surplus deliverability could be diminished in the near future. The exact timing of that is difficult to estimate because of the number of factors that impact each of these trends.

The R&D programs recommended for funding in the INGAA statement to the Subcommittee would help increase natural gas discoveries from unconventional sources to increase the amounts of gas supplies in the longer term.

Q2: DOE Secretary Herrington recently announced a major new study to perform a comprehensive assessment of the U.S. natural gas reserve potential. Why is such a study needed at this time?

A2: The Interstate Natural Gas Association of America (INGAA) supports the DOE effort as a step towards allowing natural gas to assume its proper position as a key national resource and an important component of our energy supply.

The nation's natural gas resources are expected to play a critical role in the U.S. energy supply portfolio over the near term as well as for the next decades to help check the increasing reliance on imported crude oil and to help achieve national environmental goals.

It is critical for government policymakers and private investors to be aware of the magnitude of our domestic natural gas resources while deciding on national policies or capital investments that involve a major role for natural gas. The DOE effort should provide an unbiased and comprehensive assessment of the U.S. natural gas resources for the consideration of public and private decisionmakers.

In addition, the study is timely because recent controversial reports from the U.S. Geological Survey (USGS) indicate significant reductions in domestic natural gas resources from what was previously reported. The DOE study would help clarify the reasons for the USGS lower estimates which seem to have ignored certain geographic locations (federal off-shore leases) and unconventional natural gas resources.

Q3: What funding level does the gas industry recommend for phosphoric acid fuel cells?

A3: The gas industry supports a generic program to help reduce the cost and complete the demonstration of a phosphoric acid fuel cell unit. However, INGAA did not recommend any specific allocation to this technology of the $22.7 million recommended for DOE's fuel cell program.

[Whereupon, at 12:45 p.m., the hearing adjourned to reconvene at the call of the Chair.]

APPENDIX 1

ADDITIONAL STATEMENTS FOR THE RECORD

Statement of Y. C. L. Susan Wu
Professor
Energy Conversion R&D Programs
The University of Tennessee Space Institute
Tullahoma, Tennessee 37388-8897

Submitted to the

Subcommittee on Energy Research and Development
Committee on Science, Space, and Technology
U. S. House of Representatives
Washington, D. C. 20515
March 3, 1988

Madam Chairwoman and Members of the Subcommittee, I appreciate the opportunity to submit this statement describing the progress in magnetohydrodynamics (MHD) research and development at The University of Tennessee Space Institute during the past year. Significant advances continue to be made in all phases of the MHD technology. These advances are possible only because of the continuing support of the Congress for this vital technology. I sincerely appreciate the support of this Subcommittee in the past and solicit your continued support in the future for this program.

Magnetohydrodynamics (MHD) is the 'high tech' of coal technology. MHD is the energy conversion technology which holds the potential for achieving the highest plant efficiencies while exceeding all standards for environmental intrusion without additional expensive exhaust gas cleanup systems. In addition to stationary electric power plant applications, MHD power generation is ideally suited for special applications when large quantities of power are required for short periods of time. Typical applications would include geophysical research, powering large wind tunnel test facilities, and application as power supplies for weapons systems. It has been reported that the Soviet Union used a 15 MW_e MHD generator to power a laser in 1985.

Conventional coal-fired power plants burning high- or medium-sulfur coal currently require flue gas scrubbers to reduce the sulfur dioxide emissions to acceptable levels. MHD plants can eliminate the need for scrubbers since the potassium seed material, used to enhance the conductivity of the combustion gases, acts as a sulfur scavenger to remove the sulfur dioxide. Virtually all of the SO_2 can be removed from the exhaust gases. Furthermore, emissions of nitrogen oxides (NO_x) from the MHD system are reduced to levels well below mandated standards using a staged-combustion technique. Either an electrostatic precipitator (ESP) or a baghouse, both standard state-of-the-art equipment for coal-fired power plants, can control MHD system particulate emissions to below mandated levels. Finally, the increased efficiency of the MHD system results in reduced emissions of all pollutants, including carbon dioxide (CO_2) which is thought to be a major contributor to the 'greenhouse effect' that is attracting the attention of scientists today. The higher efficiency of MHD energy conversion will also result in reduced thermal pollution - both water and air - and reduced cooling water requirements.

The Department of Energy's Coal Fired Flow Facility (CFFF), located on the campus of The University of Tennessee Space Institute (UTSI), is charged with the responsibility to conduct the proof-of-concept integrated testing of the steam bottoming cycle of an MHD central power generation plant. UTSI has initiated long duration experiments which are required to obtain bottoming cycle component and materials performance data for boiler and steam plant component design. Data are being obtained on ash deposition, corrosion and erosion, SO_2 and NO_x emission levels, particulate control, and heat transfer which can be used to design a near term MHD retrofit plant with minimum risk.

Research on coal-fired systems has revealed that between 1000-3000 hours exposure time is needed, as a minimum, to determine reliable corrosion and erosion data. In addition, the evaluation of particulate control devices (baghouses and electrostatic precipitators) requires extended periods of steady state operation at each condition to verify the proof-of-concept. The MHD steam bottoming plant differs from that of a conventional coal-fired system because of: (i) the presence of potassium seed, (ii) the high temperature combustion, and (iii) a different time-temperature history. For this reason, conventional steam cycle performance and materials data are not applicable to an MHD steam plant and thus it is necessary to obtain these critical design data for an MHD steam bottoming cycle. The UTSI test plans call for a minimum of 2000 hours of testing using an eastern coal, Illinois #6, and a minimum of 2000 hours of testing using a western coal, Montana Rosebud.

Researchers at the UTSI took a major step forward in magnetohydrodynamic (MHD) research this year by successfully completing the longest duration test in history of a coal-fired MHD integrated test train. The feat was accomplished at the Department of Energy's Coal Fired Flow Facility (CFFF). The CFFF is the only coal-fired MHD facility in the world that contains a complete simulation of the steam bottoming cycle components.

Researchers from Mississippi State University provided advanced diagnostics instrumentation for obtaining critical data on the test train. Researchers from the Babcock & Wilcox Company and Argonne National Laboratory participated in the test as monitors and advisors. Data obtained at the CFFF are transferred to the boiler manufacturers directly and immediately so that the new technology developed can be used to expand our industry in an optimum manner.

The test resulted in operation of the coal-fired MHD system for a total of 205 hours on coal. The previous record for long duration testing of a coal-fired MHD system was 70 hours and was accomplished at the CFFF in 1986. The significance of the accomplishment is evident in that in the early 1980's, test runs of five to ten minutes were considered long in a coal-fired MHD system.

The objective of the test was to obtain data on steam bottoming system components during coal-fired operation over a period of 200 hours while simultaneously verifying the reduced level of emissions of sulfur dioxide, nitrogen oxides and particulate observed during previous coal-fired MHD test periods of significantly shorter duration. Sulfur dioxide emissions resulting from the combustion of high sulfur Illinois No. 6 coal (approximately 4% sulfur) were experimentally verified to be virtually nonexistent at a potassium-to-sulfur molar ratio of 1.5 in the MHD system. Emissions of nitrogen oxides (NO_x) were less than one-third of the New Source Performance Standards (NSPS) level. Particulate emissions were also well below the NSPS acceptable levels.

In addition to measuring the level of emissions of SO_2, NO_x and particulate, specific data were obtained on: (i) materials erosion and corrosion, (ii) performance of particulate cleanup devices, primarily the baghouse and electrostatic precipitator, and (iii) ash deposition, slagging and fouling in the superheater and air heater. The data are required because the presence of potassium, required to produce electrical conductivity for the MHD system, together with the higher than standard temperature of the coal combustion (5000 degrees F), changes the characteristics of the flue gas and fly ash in an MHD system. The data represent the first step in evaluating the long term effect of potassium on materials erosion and corrosion in the superheater and air heaters, and on the performance characteristics of the bottoming cycle components.

The University of Tennessee Space Institute will continue to actively pursue the goals established in the Department of Energy's multiyear program in coal-fired MHD systems proof-of-concept testing in the Coal Fired Flow Facility. Future plans include continued integrated bottoming cycle testing to accumulate the necessary minimum 2000 total hours using an eastern coal, Illinois #6, and minimum of 2000 total hours using a western coal, Montana Rosebud. During Fiscal Year 1989, the CFFF will be modified to permit handling of a typical western coal, Montana Rosebud. Modifications will also be made in the ash handling system and tube banks of the bottoming cycle components to obtain data at test conditions which will be established by the ongoing DOE retrofit studies. UTSI is also actively developing the Formate seed regeneration process as part of the DOE seed regeneration proof-of-concept program.

In addition to activities in proof-of-concept testing of an integrated steam bottoming cycle, the staff of UTSI is working on both of the DOE retrofit study teams as a subcontractor. The UTSI role involves recommending bottoming cycle component specifications and environmental controls.

MHD is truly a developing 'clean coal technology' with substantial advantages for fossil-fueled electrical power generation. The significant environmental benefits have been experimentally verified. MHD technology is readily adaptable to retrofit existing coal-fired power plants in an environmentally acceptable manner. The United States is currently the world leader in coal-fired MHD technology, although efforts in many other nations are being accelerated. Continued development of coal-fired MHD technology will ensure the United States an efficient, clean, reliable electrical power source for the future, utilizing our most abundant energy resource, coal.

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STATEMENT OF DR. B. R. ARORA
CHAIRMAN OF THE
EDISON ELECTRIC INSTITUTE
MHD TASK FORCE

SUBMITTED TO THE

SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
U. S. HOUSE OF REPRESENTATIVES
WASHINGTON, D. C. 20515
MARCH 3, 1988

Madam Chairwoman and Members of the Subcommittee, thank you for providing me the opportunity to submit this statement to your Subcommittee in support of a continuing aggressive national program in development of magnetohydrodynamics technology. I am Dr. B. R. Arora, and I am the Chairman of the Edison Electric Institute (EEI) MHD Task Force. The EEI is the association of electric companies. The MHD Task Force membership is comprised of representatives from electric utilities and the Electric Power Research Institute (EPRI).

The EEI MHD Task Force continues to have a strong interest in the development of magnetohydrodynamics (MHD) technology as one that can significantly enhance the utilization of coal for electric power generation in a highly efficient manner while simultaneously reducing its effect on the environment. The environmental benefits from MHD utilization are substantial and have been experimentally verified in programs sponsored by the Department of Energy. Emission levels of sulfur dioxide and nitrogen oxides from an MHD system have been proven to be well below mandated levels. In addition, the MHD technology offers significantly increased efficiency and a resulting reduced level of emissions of carbon dioxide which is thought to be a major contributor to the 'greenhouse effect' that is attracting the attention of scientists today.

The EEI MHD Task Force was formed in 1982 from a utility MHD users group, and since that time has worked closely with the U. S. Department of Energy in support of this vital technology development. The task force participated in the technical reviews and public meetings sponsored by the Department of Energy that resulted in the redirected MHD program that has been pursued by the DOE over the past several years. The task force has supported the redirected program. Specifically, we support the continued activities at the Component Development and Integration Facility in Montana, the Coal Fired Flow Facility in Tennessee, and the necessary subsystem development programs to provide hardware for testing at these facilities.

The task force strongly supports the continued development of the MHD technology. During the past several years, we have encouraged the Department of Energy to put forth a long range plan for conducting the necessary proof-of-concept testing program that would lead to development of an early MHD retrofit concept for a coal-fired electric power generating plant. We are very pleased that the Department of Energy has come forward with a proposed five-year plan for the proof-of-concept program culminating in an early retrofit to an existing power plant. The task force has reviewed the five-year plan proposed by the Department of Energy and strongly endorses the plan. We support continued funding of the national MHD program by the Congress at a level that would enable the Department of Energy to meet goals of the five-year plan.

MHD power generation is an attractive source of power because of its potential for converting domestic coal into electricity in a highly efficient and environmentally acceptable manner. The EEI Task Force expresses strong support for the program, and continued federal investment in this technology for the energy future of our nation.

BRA:jrc

AMERICAN PUBLIC POWER ASSOCIATION

2301 M STREET NW WASHINGTON DC 20037 · 202/775-8300

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April 4, 1988

The Honorable Marilyn Lloyd
Chairman
Subcommittee on Energy Research
and Development
Committee on Science, Space,
and Technology
B-374 Rayburn House Office Building
Washington, D.C. 20515

ATTN: Kathryn Holmes

Dear Mrs. Lloyd:

The American Public Power Association is pleased to submit the enclosed statement on the Department of Energy's Fiscal Year 1989 budget request for fuel cell research and development. We request its inclusion in the record of the subcommittee's March 2 and 3 hearings. Thank you.

Sincerely,

Ruth Gonze

Ruth Gonze
Assistant Director of
Government Relations

RG/sm
enclosure

AMERICAN PUBLIC POWER ASSOCIATION
2301 M STREET NW WASHINGTON DC 20037 • 202/775-8300

Statement of the
AMERICAN PUBLIC POWER ASSOCIATION
Submitted to the
ENERGY RESEARCH AND DEVELOPMENT SUBCOMMITTEE
OF THE HOUSE SCIENCE, SPACE, AND TECHNOLOGY COMMITTEE
on

DEPARTMENT OF ENERGY'S FY 89 CONGRESSIONAL BUDGET REQUEST FOR FUEL CELL RESEARCH AND DEVELOPMENT

April 4, 1988

The American Public Power Association and its member utilities have been actively involved with the development of fuel cells for electric utility generation for more than a decade. APPA is the national service organization of more than 1,750 local publicly owned electric utilities throughout the United States. Public power systems supply electricity to more than 35 million Americans, and generate about 13 percent of the electricity sold in the United States. Most public power systems are small utilities, typically serving communities of under 10,000 population.

APPA is firmly committed to the development of fuel cells as a generating option. The Department of Energy's Fiscal Year 1989 budget request for fuel cell R&D -- an 80 percent cut from FY88 appropriations -- is short-sighted and counterproductive for the national interest. The request contradicts national goals for energy efficiency, self-sufficiency, and minimal environmental impact. It is out of phase with current trends in electric generation toward smaller capacity additions and shorter lead-time technologies. It harms prospects for early commercialization by ignoring the needs of developing manufacturers for sustained and dependable support. It risks the United States' technical leadership in the face of growing -- and increasingly successful -- foreign competitiveness. And it ignores the fundamental and critical role that the federal government must play to bring fuel cell options to fruition.

Fuel cells offer unique benefits to electric consumers, as well as for other applications. Fuel cells are clean, quiet, siteable in urban areas, and can be constructed in months rather than years. Their modular design increases reliability and lessens risk by allowing "building block" expansion and shorter planning horizons. Unique operating capabilities include responsive load following, rapid ramp rates, power factor correction, and system protection. Electrical efficiencies are high, with excellent prospects for further improvements through advanced design. And fuel cells are well-suited for combined heat and power production.

DOE's distressing request for reduced fuel cell R&D funding is not new. The Reagan Administration has consistently opposed adequate fuel cell R&D funding. While Congress has generally restored funds to a significant extent, the uncertainty of consistent funding has harmed the ability of manufacturers to sustain the multiyear commitments necessary for their development efforts. Undoubtedly, too, such starts-and-stops in federal support have contributed to the narrowed lead of the United States over its international competitors.

At this critical time, when multimegawatt phosphoric acid fuel cells (PAFC) are ready for demonstration, more funding, not less, is needed. The inability to proof-test PAFCs at utility scale may also jeopardize the longer-term prospects for commercializing advanced fuel cell technologies, including molten carbonate (MCFC) and solid oxide (SOFC).

It is for these reasons that APPA's Legislative and Resolutions Committee passed the enclosed policy resolution on fuel cells on February 3, 1988 (Attachment A). The resolution finds that "successful commercial development of fuel cells requires the demonstration of the technology through a partnership that may involve manufacturers, various segments of the electric utility industry, and concerned agencies of government." An APPA staff fact sheet summarizing the unique benefits of fuel cells is also enclosed for the committee's information (Attachment B).

The Importance of Fuel Cells as an Option for Local Electrical Generation

Dramatic changes are occurring in the bulk power market, including: increased competition among utilities and between utilities and "third party" entrepreneurs; a growth in retail customers who may become energy self-sufficient through cogeneration; proposals for deregulation of wholesale rates; continuing limits to transmission access; possible domination of some markets by large firms; attacks on the federal power marketing program; tighter environment, health, and safety controls for power generation coupled with new restrictions on location of power plants; and long lead times and public skepticism about large-scale conventional power production facilities.

To address these trends constructively, there needs to be an increase in the diversity and mix of power supply possibilities. There needs to be an emphasis on power supply in more affordable, less risky, bite-size chunks. There needs to be an increase in the independence of power supply from transmission limitations or dependence on conventional combustion technology.

The public has become more active in safeguarding the quality of life. In many communities, for example, the siting and building of new distribution substations has become a difficult task. With their greater land, noise, water, and air impacts, conventional large power plants pose even more formidable siting problems.

A new approach to community and environmental standards is emerging, reflecting community desires for clean and safe technologies. This approach includes the expansion of the concept of least-cost energy services and wise resource use through cogeneration. It calls for better system security and reliability and less risk to the community's financial resources. It demonstrates a fundamentally new approach to power generation that is not subject to the inherent efficiency limits of conventional generation. And it affirms a commitment to environmentally benign and economically efficient generating technologies.

Lessons Learned from Recent Public Power Efforts

Over the past year and a half, APPA and many of its member utilities undertook an active effort to promote the demonstration of 11-MW capacity PAFC generating units. On March 3, 1988, those efforts were suspended. The lessons of that effort, however, offer a pointed commentary on DOE's drastic proposed cuts in the fuel cell R&D budget.

APPA's promotion of a fuel cell demonstration began in late 1986 with an effort spearheaded by the Electric Power Research Institute to demonstrate three 11-MW PAFC units at a cost of approximately $40 million each. APPA's Board of Directors endorsed the EPRI initiative, and the city utility of Palo Alto, California, signalled its willingness to host one of these three demonstration units, contributing $15 million and a site. The remaining funding was to be committed by other APPA members and the Electric Power Research Institute.

Unfortunately, other sectors of the electric utility industry did not commit to fund the additional two demonstration units. By the end of summer, 1987, it was clear an alternative approach was necessary if a demonstration program were to move forward.

The leadership of this second effort was assumed by APPA and its interested members. An alternative proposal for an initial 11-MW unit linked with contingency orders for early "market entry" units was proposed to the manufacturer. Within a period of about six weeks, firm interest in six of these "market entry" units was secured from various APPA members around the country. Prospects for additional orders beyond this level also looked excellent.

Two factors, however, forced the manufacturer to reject the risk of this alternate proposal: the absence of a full-scale demonstration proving the integration of all of the powerplant's major subsystems; and the large investments necessary in mass production facilities essential to drive costs down to acceptable levels for these "market entry" units.

This situation led to a counterproposal from the manufacturer for a single 10-MW demonstration, using much on-hand equipment from ongoing development and testing work. But the price tag zoomed to an estimated $70 million, including site acquisition, spare parts, and the eventual upgrade to "commercial" operation. This price tag was too high for Palo Alto and the other participants to shoulder, and the current demonstration effort was suspended.

A number of lessons emerged from these efforts:

- Collaborative arrangements between the public and private sectors are required to share the costs and risks of large-scale demonstrations of energy technologies;
- The role of the federal government as a funding participant in such demonstrations is critical;

- Market development will not occur until the technical risk is lessened through a successful demonstration of the technology;
- As long as fuel cells are hand-built Maseratis and not assembly-line-produced Fords, costs will remain high and unacceptable; and
- Continuing R&D support will help improve the basic technology, leading to higher efficiencies and lower eventual costs.

Thus, APPA has not been able to date to achieve fuel cell commercialization solely through nonfederal initiatives. Clearly, a new approach is needed to break the impasse inherent in fuel cell commercialization between technical demonstration, market development, and lower costs through mass production.

Research, Development, and Demonstration Needs

For all the reasons above, DOE's request to cut its fuel cell R&D budget by 80 percent is profoundly counterproductive. More money -- not less -- is necessary for advanced technology research and development. And much more money -- not none -- is necessary for full-scale demonstration.

Continuing R&D efforts need to be secured for all three leading approaches to multimegawatt potential fuel cells: phosphoric acid (PAFC), molten carbonate (MCFC), and solid oxide (SOFC). In addition, a strong commitment to basic research in advanced concepts needs to be secured. The comments below pertain to utility-scale fuel cells.

In terms of PAFC, DOE's R&D program should focus on five main areas: 1) fixed vs. variable cost tradeoffs; 2) smaller-scale system design; 3) manufacturing technology; 4) verification of the more advanced "configuration B" fuel cell stack; and 5) demonstration support for multimegawatt units. These areas are listed in order of increasing cost.

Both solid oxide and molten carbonate fuel cells are receiving attention from the electric utility industry. Solid oxide is being supported by the

Tennessee Valley Authority through a 3-kW development unit. Pacific Gas and Electric is supporting a 5-kW molten carbonate unit. EPRI is also focussing its advanced fuel cell support on MCFC.

Both advanced technologies should continue to receive DOE support. Though each appears to offer advantages and technical challenges, it is clear that the electric utility industry does not yet have sufficient information to suggest which alternative may be superior. The lack of a catalyst and solid state design recommend solid oxide, but problems in fabrication and perhaps lower potential efficiencies than MCFC may be drawbacks. MCFC may also be more suitable as a baseload option with higher temperature heat recovery.

The Prospective Loss of U.S. Technological Leadership

The United States still appears to have a lead in PAFC technology measured in years (itself, however, crucially dependent on the needed demonstration phase). However, material presented to the Fuel Cell Users Group in Atlanta, Georgia, on March 30, 1988, suggests the Japanese may have substantially narrowed the gap or pulled even in some aspects of MCFC technology.

Such erosion in the U.S. technological leadership in fuel cells should be alarming, and is itself a result of inadequate funding. The Japanese "Moonlight" Project, sponsored by the New Energy Development Organization (NEDO), has been making large strides in all fuel cell types. Nearly a dozen major Japanese manufacturers now have active development and demonstration programs. Efforts in Japan were described as "five to ten" years behind those of U.S. manufacturers as little as two years ago. More recent assessments narrow those gaps across the board.

Megawatt-scale demonstrations of PAFC are planned in Italy and Japan. In the U.S., only the planned Westinghouse demonstration of PAFC at its Waltz Mill facility now appears active in this size range.

In effect, the decision to scale back fuel cell R&D in the United States at this time could mean relinquishing technological leadership. Recent marketing efforts by foreign manufacturers suggest that they are targeting precisely the large potential market in the United States.

When Public Power Buys, Will the Label Say "Made in the U.S.A."?

APPA and its members will remain active in promoting fuel cell commercialization. Near-term efforts include completing APPA's own assessment of the public power market for fuel cells and completing a "Notice of Market Opportunity" (NOMO) for circulation to all potential vendors.

APPA's enclosed policy resolution calls for the Association to "communicate public power's commitment to the fuel cell option to any party in a position to promote its commercial availability." These parties include foreign, as well as domestic, suppliers. APPA and its members would obviously prefer to secure fuel cells from domestic manufacturers.

Yet technological innovation without the commitment and funding to complete the commercialization cycle may ultimately mean that the fuel cells our members acquire do not say "Made in the U.S.A."

We ask the committee's support for full and expanded funding for fuel cell research, development, and demonstration programs.

Attachment A

88-13

FUEL CELL COMMERCIALIZATION

WHEREAS, many local publicly owned electric systems seek cost-effective and acceptable methods to control future power supply;

WHEREAS, ownership of self-generation by public power systems is an important factor to secure such power supplies as well as to improve the ability to negotiate purchased power supplies;

WHEREAS, fuel cell powerplants promise superior environmental performance, high efficiencies, acceptable costs, cogeneration potential and flexible operation, in a size appropriate to the requirements of public power;

WHEREAS, because of the unique fit of fuel cell technology to the requirements of local publicly owned electric systems, public power represents a critical market for multi-megawatt fuel cells, as has been reflected in the leadership by a set of public power systems to promote the commercial readiness of the technology;

WHEREAS, successful commercial development of fuel cells requires the demonstration of the technology through a partnership that may involve manufacturers, various segments of the electric utility industry, and concerned agencies of government;

NOW, THEREFORE, BE IT RESOLVED, THAT:

1. The American Public Power Association shall support the commercial development of multi-megawatt fuel cell power plants;

2. APPA shall communicate public power's commitment to the fuel cell option to any party in a position to promote its commercial availability;

3. APPA shall continue to seek financial support to demonstrate fuel cell power plants from appropriate entities, including, but not limited to, manufacturers of fuel cell equipment, the Electric Power Research Institute, interested public power systems, the Congress, and appropriate agencies of government; and

4. APPA shall keep its membership informed on a timely basis of the opportunities to promote fuel cell development and the status of the technology's commercial readiness.

-- Adopted by American Public Power Association's Legislative & Resolutions Committee, February 3, 1988.

Attachment B

AMERICAN PUBLIC POWER ASSOCIATION
2301 M STREET NW WASHINGTON DC 20037 • 202/775-8300

April, 1988

THE UNIQUE BENEFITS OF FUEL CELLS

A Fact Sheet by
Michael K. Bergman
Director of Energy Research

Fuel cells offer advantages in efficiency, reliability, economy, cleanliness, unique operating characteristics, planning flexibility, and future development potential. These benefits are summarized below.

Fuel Cells Offer High Efficiencies and Reliability

The fuel cell can convert up to 80 percent of the energy from its supply fuel into useable electric power and heat. Current phosphoric acid fuel cell (PAFC) designs offer 41 percent electrical conversion efficiency on a high-heating value basis, with 46 percent electrical conversion efficiencies for PAFC possible in the near-term through currently known science and engineering. The Electric Power Research Institute has estimated that advanced molten carbonate fuel cells (MCFC) may achieve electric efficiencies greater than 60 percent, exclusive of a topping cycle which would raise efficiencies even higher. Such efficiencies are unprecedented. Furthermore, a fuel cell's efficiency is largely independent of its size. Fuel cells can operate at half their rated capacity while maintaining high fuel-use efficiencies.

Fuel cell power stations located close to loads can also reduce costly transmission lines and transmission losses.

Another important attribute of the fuel cell is its ability to cogenerate: that is, to produce hot water and lower-temperature steam at the same time it generates electricity. Its ratio of electric to thermal output is approximately 1.0, while for a gas turbine the ratio is about 0.5. This advantage means that a fuel cell matched to a thermal load will have approximately twice the electric output of a combustion turbine matched to that same load. In smaller sizes, of interest to most public power systems, fuel cells are also more efficient (by about a factor of two) when compared to, for example, the 15,000 Btu/kWh heat rate of a 2-MW combined cycle system. The fuel cell's load following capability, while maintaining high efficiency, may also give it an advantage in cogeneration markets with varying heat demands.

Fuel cell systems should have higher reliability than combustion turbine-combined cycle systems or internal combustion engines because they contain fewer moving parts. Fuel cells will not experience catastrophic failure as a combustion turbine or internal combustion engine will when rotating parts fail; they experience only a gradual loss of efficiency. Mature fuel cell systems are expected to have higher availabilities than competing technologies.

Fuel Cells Have Unparalleled Environmental Performance

Substitution of fuel cells for conventional power plants should improve air quality and reduce water consumption and wastewater discharge. The generation of electricity now produces more particulates, sulfur oxides and nitrogen oxides than all other stationary sources combined. Fuel cell power plant emissions are ten times lower than those specified by the most stringent environmental regulations require. Fuel cells also produce lower carbon dioxide ($CO2$) emissions than conventional generation, a question of increasing concern due to the so-called "greenhouse effect."

Because the electrochemical reaction of the fuel cell produces water as a byproduct, little if any external water is required for power plant operation. This low water use is in marked contrast to large steam electric power plants that require massive quantities of water for cooling. Wastewater discharges from fuel cell systems are also lower and the quality is superior compared with conventional fossil-fueled power plants, requiring no pretreatment prior to disposal in many communities. Fuel cells eliminate or reduce water quality problems associated with thermal discharges, power plant site runoff, and the disposal of wastes from air emission controls.

The quiet, electrochemical nature of fuel cells eliminates many of the sources of noise associated with conventional steam-powered systems, thus easily complying with OSHA standards. No ash or large volume wastes are produced from fuel cell operation. Land requirements are acceptable, and connecting transmission corridors are not required as is the case with outside power sources. Because of their comparatively small size, absence of a combustion cycle, state-of-the-art safety systems, and low pollutant emissions, fuel cells are among the least hazardous methods of energy conversion.

Fuel Cells Have Unique Operating Characteristics

Fuel cells have beneficial operating characteristics matched by no other technology. These characteristics save costs in meeting system operating requirements. Dynamic operating benefits include load following, power factor correction, quick response to generating unit outages, and control of distribution line voltage and quality control.

The power conditioner unit of the fuel cell power station can be used to control real and reactive power independently. Control of power factor and line voltage to meet load can minimize transmission losses and reduce requirements for reserve capacity and auxiliary electrical equipment such as capacitors, tap-changing transformers, and voltage regulators.

When new generating capacity is added to an electric power system, substation equipment sometimes has to be upgraded because of the expectation of increased fault current (which lowers the reliability of the electric system). However, with fuel cell power units, it is not necessary to upgrade the fault-current interrupting capability of existing substation equipment, because the fuel cell power units have a short-circuit ratio of about 1:1. The fuel cell also controls disconnect if it is necessary.

Fuel cells can easily regulate deviations from system frequency on an area-by-area basis. This benefit leads to an increase in overall system stability and overcomes the present fuel penalties that result from the need to switch to other (often oil-fired) generating units to meet the deviations in frequency caused by localized variations in load in the system.

Fuel cell units have an excellent part-load heat rate and can respond rapidly to transient loads. For example, the heat rate of a phosphoric acid demonstration unit is anticipated to be 8,300 Btu/kWh at rated power and to increase slightly at 50 percent of rated capacity. Also, it is expected to be able to go from 30 percent of rated power to rated power in only 7 seconds. Spinning reserve requirements can thus be lessened when fuel cells are used.

One of the recurring problems facing energy control dispatchers is how to operate the system during periods of high load pickup, so there is sufficient generation to follow the load pickup, while still maintaining reserve or regulating margin. Dispatchers typically meet this "regulatory margin" by loading more expensive units above their economic assignment early in the load pickup period. The cost penalty for these inefficiencies can be overcome by keeping fuel cells on-line longer and using their high part-load efficiencies.

Fuel cell power plants are also designed for unattended operation.

Fuel Cells Provide Planning Flexibility

Planning flexibility, including modularity, results in strategic and financial benefits to the utility and its customers. Because fuel cell power plants may be built within two years of order, and because performance is largely independent of plant size, they can be used to increase utility system capacity by small increments in response to customer needs.

By better matching increases in electric demand, long periods of overcapacity are avoided, lowering average fixed costs over time. And, if demand growth is uncertain, the fuel cell's short lead time becomes even more valuable. A utility can slow or accelerate its response to growth. Also, as experience is gained with fuel cells, utilities may be able to reduce required reserve margins while maintaining the same reliability, resulting in lower fixed costs.

The community benefits from the increased reliability from smaller units distributed throughout the grid. And, placing generation at the distribution level reduces the likelihood of outages due to external transmission interruptions.

Though initial fuel cells will be designed to be fueled with either natural gas or naphtha (a widely available, low-cost refinery product), the cells require hydrogen. The so-called reformer that produces this hydrogen-rich gas allows the use of a variety of low-sulfur gaseous and liquid fuels. Advanced fuel cells should also be able to operate on gasified coal.

These planning flexibilities are not all unique to fuel cells. Combined-cycle units and internal combustion engines each share some of these flexibilities. But combined with their other advantages, fuel cells are truly a unique energy resource.

Fuel Cells Have Future Potential

The potential of fuel cells to break through the efficiency barriers now being met by all conventional generation cannot be overemphasized.

As a developing technology, the phosphoric acid fuel cell should see significant efficiency improvements. Over the next 15 to 20 years, more advanced fuel cell designs based on molten carbonate or solid oxides may be able to demonstrate quantum leaps in efficiency improvements.

The fuel cell's competitors, on the other hand, including gas turbines and internal combustion engines, are at a mature stage of development. Small incremental improvements are the most that can be expected from these technologies. And improvements in conventional technologies will come at the expense of higher operating temperatures and, therefore, greater nitrogen oxide air pollution.

-- The American Public Power Association is the national service organization representing more than 1,750 local publicly owned electric utilities throughout the country.

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Charles H. Goodman
Vice President

the southern electric system

March 17, 1988

The Honorable Marilyn Lloyd, Chairman
Subcommittee on Energy Research and Development
Committee on Science, Space, and Technology
U.S. House of Representatives
Washington, D.C. 20515

Dear Congresswoman Lloyd:

Attached is written Testimony that Southern Company Services, Inc., requests be included in the record of the March 3, 1988, hearings before the Energy Research and Development Subcommittee of the House Committee on Science, Space, and Technology. This Testimony requests Congressional support for continued operation of the Wilsonville Advanced Coal Liquefaction Research and Development Facility in Wilsonville, Alabama. The Wilsonville pilot plant is the only facility in the United States that can conduct engineering-scale research on direct coal liquefaction processes. With increasing dependence on imported oil, the United States is becoming more vulnerable to another oil crisis and hence, the research being performed at Wilsonville is becoming more important.

The economics of direct liquefaction continues to improve. The latest estimated cost for producing coal-derived fuels is $35 per barrel, down from over $90 per barrel in the early 1980's. If direct liquefaction technology can be commercialized, it will reduce U.S. dependence on imported oil, reduce the possibility of future energy crises, and reduce the U.S. balance of trade deficit.

If you have any questions, or need additional information about this testimony, please contact Mr. Gary Styles of my staff.

Sincerely,

Gary C. Styles
Charles H. Goodman

:0430A

Attachment

cc: Members of Subcommittee on Energy Research
and Development

THE FY 1989 FOSSIL ENERGY BUDGET PROPOSAL

Testimony of
Charles H. Goodman, Ph.D.
Vice President, Research and Environmental Affairs
and
Gary A. Styles
Project Manager, Coal Liquefaction Technology
Southern Company Services, Inc.
to the
Committee on Science, Space, and Technology
Subcommittee on Energy Research and Development
U.S. House of Representatives

March 18, 1988

Ms. Chairman and Members of the Committee:

Summary

The purpose of this submittal is to request authorization for the continued operation of the Wilsonville Advanced Coal Liquefaction Research and Development Facility. The continuation of this project is of vital importance to the energy security of the United States because we continue to be vulnerable to another oil crisis through either high prices or shortages. Direct coal liquefaction can cap the price the United States pays for imported oil and can also help reduce the trade deficit. The coal liquefaction research program at Wilsonville has resulted in significant improvements in the economics of coal-derived liquids - for example, a 60 percent decrease in cost between 1983 and the present. However, more work needs to be completed before coal-derived liquids can economically compete with petroleum. The objective of the Wilsonville research program is to reduce the cost of coal-derived liquids from the present cost of $35 per barrel to $28 per barrel, an oil price that could be reached in the next five years even without a crisis. Over the next two years, the Wilsonville project plans to focus its research on obtaining higher yields from bituminous coals, on testing less expensive coals, and on improving catalysts and process configurations. If this can be accomplished, it may be possible to have this technology ready before another oil crisis occurs. If the Wilsonville program is terminated, the government will have to spend $30 to $50 million during the next oil crisis to build and operate a similar facility. More important, it will take at least five years to re-learn the operating and maintenance techniques that are presently well understood at Wilsonville.

Introduction

Due to declining domestic petroleum reserves and production, increased domestic oil consumption, and increased dependence on imported oil, the United States is very vulnerable to another oil crisis. Presently, oil is the major source of transportation sector fuels and there are no available near-term alternatives. With continued research, direct coal liquefaction can potentially provide an alternative fuel source in as little as 5 to 10 years. Recent developments have shown that as much as 78 percent of low-ash, high-carbon eastern bituminous coals can be converted into distillate fuels. In addition, revised estimates of the economics of direct coal liquefaction technologies show that the cost of producing coal-derived liquids has been reduced from $93 per barrel in 1983 to $35 per barrel in 1987 through improvements in technology and plant design. If commercialized, coal-derived liquid fuels can reduce U.S. dependence on imported oil and can also reduce the U.S. balance of payments deficit.

Wilsonville is the largest operating coal liquefaction pilot plant in the United States but it is also the smallest size at which steady-state evaluations of advanced coal liquefaction technology can be conducted. The facility, which was built without federal funds, cost over $25 million to construct. In addition, an important resource at Wilsonville is a staff of 100 experienced engineers, chemists, operators, and maintenance personnel with an average of over 10 years experience in coal liquefaction research. Wilsonville has the reputation of being one of the best coal liquefaction research projects in the world. Japan, the United Kingdom, Canada, Australia, and the People's Republic of China all continue to support development of direct coal liquefaction as a method of reducing dependence on imported oil. If the Wilsonville program is terminated, the United States will lose its leadership in this technology which it needs in order to be ready for the next oil crisis.

U.S. Dependence on Imported Oil

The Wilsonville project is crucial to the continued energy security of the United States. For the past eight years, the present Administration has had only a loosely-focused, short-term energy policy. The basis for this assumption has been that the private sector (major oil companies) would act to protect the national interest by continuing research in energy alternatives. This short-sighted position has failed as evidenced by reduced research in advanced energy supply technologies by the private sector and by increased dependence on imported oil. As a result, the United States faces the possibility of a another major oil crisis in as little as five years.[1,4]

Less than three years ago, 27 percent of the U.S. oil supply was imported. In 1987, the foreign share was about 40 percent and is expected to rise to 50 to 70 percent in the 1990's.[1,3] In 1987, the cost for imported oil was $47 billion. By the year 2000, the import oil bill is estimated to be $200 billion. Large oil imports not only leave the United States vulnerable to oil embargoes and energy crises, they also adversely affect the U.S. trade deficit and the ability to pay for imports.[4] In 1987, imported oil accounted for $40.8 billion, or 24 percent of the total U.S. trade deficit.

The increase in U.S. dependence on imported oil is caused by both increased oil consumption due to lower oil prices and by declining oil production due to decreased exploration. Oil consumption was five percent higher in mid-1987 than it was for the corresponding period in 1985. Drilling activity in the United States reached a post-World War II low during 1986.[1] In 1981, as many as 4,500 drilling rigs were active. For the period 1982-1985, an average of 2,400 rigs was active. This level of activity was just sufficient to maintain a constant level of reserves. In the last half of 1986 and first half of 1987, only 800 rigs were active. While the full effect of this drop on production has yet to be felt, crude oil production has already dropped from 9.1 million barrels per day in February, 1986, to 8.3 million barrels per day in January, 1987.[4]

The major reason for this drop in drilling activity and production is low oil prices. According to Robert L. Hirsch, Vice President for ARCO Oil and Gas Company, "Because people are generally happy with lower energy prices, and because the country tends to be short-term oriented, there appears to be a low probability of action before the problem becomes severe."[1]

The current volatility in oil prices has adversely affected petroleum industry planning. The lag between planning and new production is on the order of 5 to 10 years. If another energy crisis occurs, it will take 5 to 10 years before the U.S. economy can adjust as evidenced during the crises of the 1970's.

The principal importance of oil is that it is presently the primary source of fuel for motor vehicles and aircraft. Moreover, oil represents one-fourth of the total U.S. energy use and is the only major energy resource in which the United States produces less than it consumes. While natural gas or coal can be used to replace oil for some industrial applications, most conversions to natural gas have already been made. Unlimited, low-cost natural gas cannot be relied upon to reduce U.S. dependence on imported oil. The high rate of drilling for natural gas between 1980 and 1986, compared to the 1970's, did not increase reserves because natural gas was being consumed at the rate at which it was being discovered. In the first half of 1987, drilling for natural gas was 33 percent below the same period in 1986. The impact of this reduced drilling activity has not yet been felt but will ultimately result in decreased supply and increased cost for natural gas.[1,4]

While the United States is deficient in oil supply and production capability, it does have abundant resources of coal and oil shale that can be used to eliminate dependence on imported oil and reduce the balance of payments deficit. It is estimated that 625 billion barrels of liquid fuels can be produced from coal and oil shale, which far exceeds Saudi Arabia's present 166 billion barrels of reserves.[2]

Most of these arguments have been made before and were a primary justification for the synthetic fuel development programs of the late 1970's and early 1980's. Results from those programs showed that liquid fuels would cost as much as $93 per barrel. For a number of reasons, the present Administration eliminated support for further development of clean liquid fuels. In the face of this indifference, Congress has continued to support clean liquid fuel research at minimum levels throughout the 1980's through basic laboratory research and at pilot scale facilities such as the Wilsonville Advanced Coal Liquefaction R&D Facility. As a result, coal liquefaction technology has continued to improve. Amoco Corporation recently revised the estimated cost of coal-derived liquid fuels. The revised cost estimate was based on improvements made at the Wilsonville Advanced Coal Liquefaction R&D Facility, on design improvements, and on changes in U.S. economic factors. Amoco's latest estimate shows that the cost, based on these improvements, of coal-derived liquids is down to $35 per barrel, a 60 percent decrease since 1983.[5]

Wilsonville Accomplishments

Some significant recent accomplishments of the Wilsonville facility are:

- From 1982 to 1985, integrated two-stage liquefaction (ITSL) was developed and demonstrated at steady-state conditions. Using an integrated system of a thermal reactor for the first stage and an ebullated-bed catalytic reactor as the second stage, 60 percent of typical eastern bituminous coal was converted to distillate fuel. This was a significant increase over previous systems, which typically converted 50 percent or less into distillate fuel. It was this breakthrough which caused Amoco to re-evaluate its cost estimate for coal derived liquids.
- In 1984, over 50 percent distillate was produced from low-rank western subbituminous coal by using an inexpensive disposable catalyst in the ITSL process.
- In 1985, the objective of the Wilsonville program was changed to emphasize research into fuels that can be used in the transportation sector rather than clean boiler fuels as in the early 1980's.
- In 1986, a mathematical model was completed which simulates the Wilsonville ITSL process.
- In 1987, staff was reduced by 15 percent and operating cost were reduced by 7 percent due to reduced funding. The quality of the research program was only minimally affected. The project is currently at minimum staffing for an effective research program.
- In 1987, a second ebullated-bed catalytic reactor was added and research into close-coupled two-stage liquefaction began. In late 1987 and early 1988, 78 percent distillate yield was produced from low-ash, high-carbon Appalachian coal.

Wilsonville Goals

The goal of continued coal liquefaction research at Wilsonville over the next two years is to reduce the cost of coal-derived liquids from the current $35 per barrel by another 20 percent to $28 per barrel. It is not unreasonable to expect oil prices to reach $28 per barrel in the next five years under non-crisis conditions. If coal-derived fuels can be produced for $28 per barrel, there is a reasonable possibility of commercializing direct liquefaction before the next oil crisis occurs. If coal liquefaction can be commercialized under non-crisis conditions, the price the United States has to pay for imported oil will be effectively capped. Commercialization can also help reduce the trade deficit by replacing imported oil with fuels produced from the domestic coal reserves. Research over the next two years will focus on:

- low-ash, high-carbon eastern bituminous coals which may increase the quantity of distillate yields.
- low-quality Southeastern lignites which may lower the operating cost (lower coal cost) of coal liquefaction plants.
- improved catalysts which may lower capital and operating cost, increase distillate yields, and improve product quality.
- improved process configurations which may lower capital and operating costs.

Wilsonville Capabilities and Private Sector Cost Sharing

The Wilsonville pilot plant has several unique features that make it well suited for continued coal liquefaction research. These include:

- A staff of 100 experienced engineers, chemists, operators, and maintenance personnel with an average of over 10 years experience in synthetic fuel research.
- Proven capital equipment valued at over $25 million that was purchased with funds from non-government sources [Electric Power Research Institute (EPRI), Southern Company Services (SCS), and Kerr-McGee Corporation]. The Wilsonville pilot plant includes two ebullated-bed catalytic reactors, an efficient Kerr-McGee Critical Solvent Deashing unit for ash removal, and all necessary support equipment such as waste water treatment and data acquisition systems.
- A non-proprietary research program that is designed to disseminate as much information as possible to industry.

Cost sharing for the Wilsonville project is provided by EPRI, Amoco Corporation, and SCS. Through 1987, almost 40 percent of the total project cost of $113.3 million has been provided by the above mentioned co-sponsors. All capital costs are paid by EPRI. In 1988 and 1989, we estimate that a minimum of $750,000 per year will be provided by co-sponsors. SCS is actively seeking additional private sector co-sponsors. In addition to cost sharing, SCS will implement changes in the project organization that will save DOE $600,000 to $700,000 per year beginning FY'89.

:0429A

References

1. "Impending United States Energy Crisis," Robert L. Hirsch, Science, Vol. 235, March 20, 1987, p. 1467-1472.

2. "Petroleum Research Centers," Philip H. Abelson, Science, Vol. 237, July 10, 1987, p. 117.

3. "U.S. Dependence on Oil Imports is Shooting Up But Congress, White House Fumble With Policy," Robert E. Taylor, The Wall Street Journal, June 19, 1987.

4. "Energy Futures," Philip H. Abelson, American Scientist, Vol. 75, November-December, 1987, p. 584-593.

5. "Recent Progress in Direct Coal Liquefaction," Robert E. Lumpkin, Science, Vol. 239, February 19, 1988, p. 873-877.

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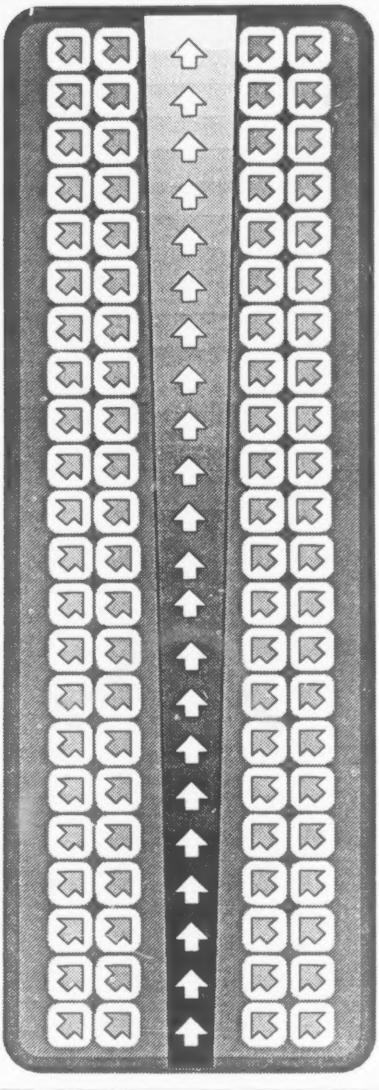
APPENDIX 2

ADDITIONAL MATERIAL FOR THE RECORD

DOE/FE-0104



MHD Program Plan

FY 1988

U.S. Department of Energy

Assistant Secretary for Fossil Energy

Deputy Assistant Secretary for Oil, Gas, Shale and Special Technologies

April 1988

DOE/FE-0104

MHD Program Plan

FY 1988

April 1988

U.S. Department of Energy
Assistant Secretary for Fossil Energy
Deputy Assistant Secretary for Oil, Gas,
Shale and Special Technologies

Washington, D.C. 20545

PREFACE

This document was prepared in response to Congressional direction to implement a cost-shared magnetohydrodynamics (MHD) proof-of-concept (POC) program. The POC program was established as a result of a series of public meetings, and the consensus views were embodied in a preliminary program plan that was submitted to the Congress in June 1984.

The Department has contracts in place to implement a five year POC program. However, the Department is proposing to terminate the program in FY 1989 because it believes that the pursuit of the long range, high risk MHD development program is not affordable in light of the current year fiscal constraints. The cost estimate, in 1988 dollars, to fund the program for the five year period 1988-1992 is about $172 million. That would require about one out of every ten dollars in the total fossil energy budget with considerable uncertainty regarding potential gains. The subsequent technology -- a retrofit demonstration by the private sector -- could require expenditures of $200 million to $400 million in current year dollars over a ten year period.

Table of Contents

Section		Page
	Executive Summary	1
I.	**Overview of Magnetohydrodynamics**	9
II.	**Technology Status**	13
	Integrated MHD Topping Cycle	13
	Combustor	
	Nozzle	
	Channel	
	Superconducting Magnet	
	Diffuser	
	Power Control and Conditioning	
	Feed Systems	
	Integrated MHD Bottoming Cycle	19
	Radiant Furnace	
	Secondary Combustor	
	Steam Superheater, Reheater, and Economizer	
	Air and Oxidant Heaters	
	Electrostatic Precipitator or Baghouse	
	Seed Regeneration	23

Table of Contents (continued)

Section **Page**

III. **Planned FY 1988 Research and Development** 25
- Introduction 25
- Integrated MHD Topping Cycle 26
  - *Combustor*
  - *Channel*
  - *Power Conditioning Circuits and Inverters*
  - *Magnet*
- Integrated MHD Bottoming Cycle 29
- Seed Recovery/Regeneration Process 30
- System Engineering, Supporting Research, and Retrofit Activities 31
- System Integration 32

IV. **International Activities** 37

List of Exhibits

Exhibit No.	Title	Page
1	Magnetohydrodynamic Electric Power Plant	2
2	MHD Development Program	4
3	MHD Development Schedule	6
4	Principle of MHD	8
5	Typical Open Cycle MHD System Component Arrangement	11
6	Coal Fired MHD Systems Development	26
7	Principal Program Participants	34-35
7a	Topping Cycle POC	34
7b	Bottoming Cycle POC	34
7c	Seed Regeneration POC	35
7d	Retrofit Conceptual Design	35

EXECUTIVE SUMMARY

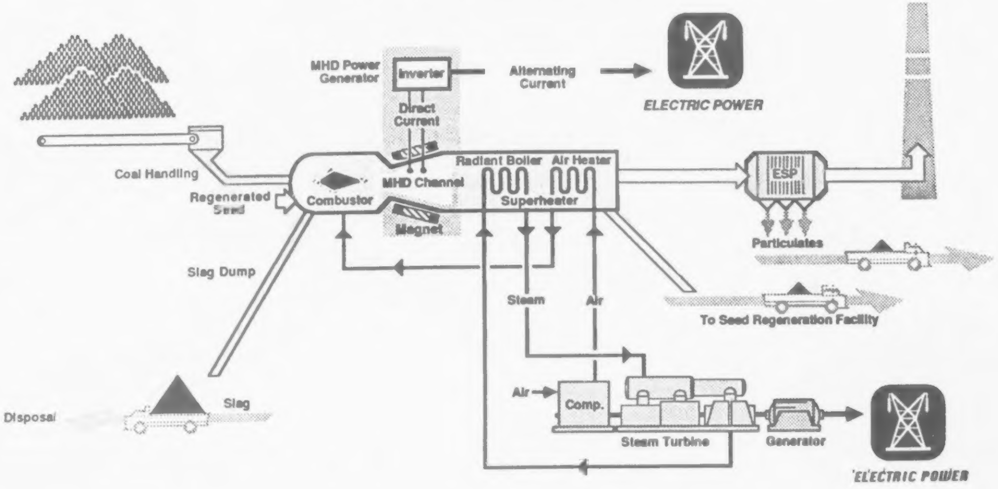
A principal objective of the Department of Energy (DOE) Office of Fossil Energy is to improve and increase the use of U.S. coal, both domestically and internationally. Research and Development (R&D) focused on substantially improving the environmental, technical, and economic performance of coal-based systems will help to achieve that goal. Several advanced coal technologies are now under development by DOE, including magnetohydrodynamics (MHD).

The National Energy Policy Plan projects the need for a significant additional electric generating capacity to meet future demands, to replace aging facilities, and to provide effective reserve margins.

Magnetohydrodynamic power generation is a method for converting thermal energy directly to electric power. A simplified flowchart for an MHD power plant is illustrated in Exhibit 1. An MHD power generation system would convert high temperature heat directly into electricity with potential efficiencies in the 50-60 percent range. An additional advantage of this system is the direct use of a wide range of coals without harmful compounds being released. The MHD system inherently removes sulfur from the combustion of coal, thereby making it possible to control and substantially reduce sulfur dioxide (SO_2) emissions. Nitrogen oxides (NO_x) are reduced by controlling the rate of temperature decay in the combustion gases, and particulates are reduced with commercially available electrostatic precipitators or baghouses.

Exhibit 1

MagnetoHydroDynamics
ELECTRIC POWER PLANT


MHD Power Generator
Inverter
Direct Current
Alternating Current
ELECTRIC POWER
Coal Handling
Regenerated Seed
Combustor
MHD Channel
Magnet
Radiant Boiler
Air Heater
Superheater
ESP
Particulates
Slag Dump
Steam
Air
To Seed Regeneration Facility
Disposal
Slag
Air
Comp.
Steam Turbine
Generator
ELECTRIC POWER

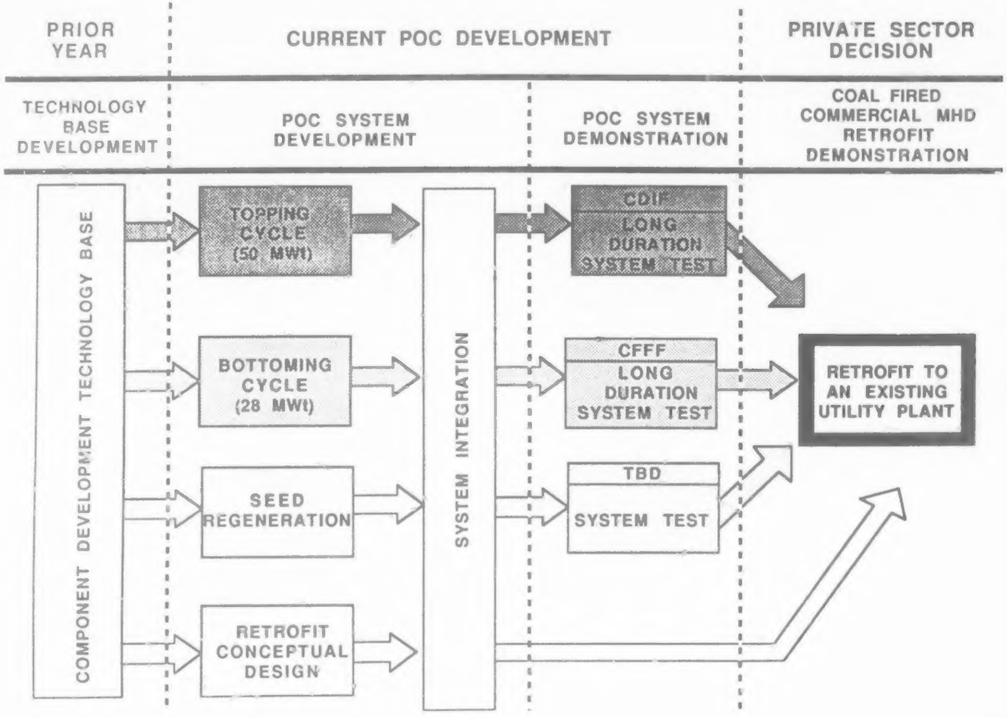
The use of MHD offers the potential of lowering the cost of electricity while reducing environmental emissions to levels well below the current NSPS requirements. The current MHD program being implemented is a result of a concensus established in public meetings held by DOE in 1984. The public meetings were followed by the formulation of a June 1984 Coal-Fired MHD Preliminary Transition and Program Plan. This plan focused on demonstrating the proof-of-concept (POC) of coal-fired MHD electric power plants by 1992. The resulting program is focused on the least-cost, shortest development time path to establish the MHD technology base needed for private sector commercialization of the technology. The program logic is shown in Exhibit 2.

MHD test data indicate that while there are no fundamental technical barriers impeding the development of MHD power plants, technical risks remain. Future key milestones and program decision points have been identified, and an engineering development program -- the POC program -- has been formulated. In order to reduce the costs and accelerate the POC effort, three key subsystems -- topping cycle, bottoming cycle, and seed regeneration, are to be assembled and tested separately, at different locations. Also to reduce costs, the POC program does not call for fabrication of complete superconducting magnets, but rather the fabrication and testing of superconductor cables. The POC topping cycle system demonstration can be achieved using a conventional iron core magnet system. The objective of this program is to develop the specific data base needed for the private sector to make its final decision on whether to proceed with the design and construction of a fully integrated, commercial prototype retrofit plant.

This program is guided by systems engineering-derived requirements and analytical modeling to support scale-up and component design. In response to environmental, economic, engineering, and utility-acceptance requirements, design choices and operating modes will be tested and refined to provide technical specifications for meeting commercial criteria. These engineering activities will be supported by comprehensive and continuing systems analyses to establish realistic technical requirements and cost data. Trade-off studies will be carried out to direct the overall system concept

Exhibit 2

MHD Development Program


PRIOR YEAR
CURRENT POC DEVELOPMENT
PRIVATE SECTOR DECISION
TECHNOLOGY BASE DEVELOPMENT
POC SYSTEM DEVELOPMENT
POC SYSTEM DEMONSTRATION
COAL FIRED COMMERCIAL MHD RETROFIT DEMONSTRATION
COMPONENT DEVELOPMENT TECHNOLOGY BASE
TOPPING CYCLE (50 MWt)
BOTTOMING CYCLE (28 MWt)
SEED REGENERATION
RETROFIT CONCEPTUAL DESIGN
SYSTEM INTEGRATION
CDIF
LONG DURATION SYSTEM TEST
CFFF
LONG DURATION SYSTEM TEST
TBD
SYSTEM TEST
RETROFIT TO AN EXISTING UTILITY PLANT

toward the most advantageous designs. These system studies are essential to focus the MHD engineering development program on commercially realistic goals, which will be validated by participating utilities, potential industrial users, utility equipment manufacturers, and other key industry groups.

The essential elements of the current program, which are based on the June 1984 Coal-Fired MHD Preliminary Transition and Program Plan, are to:

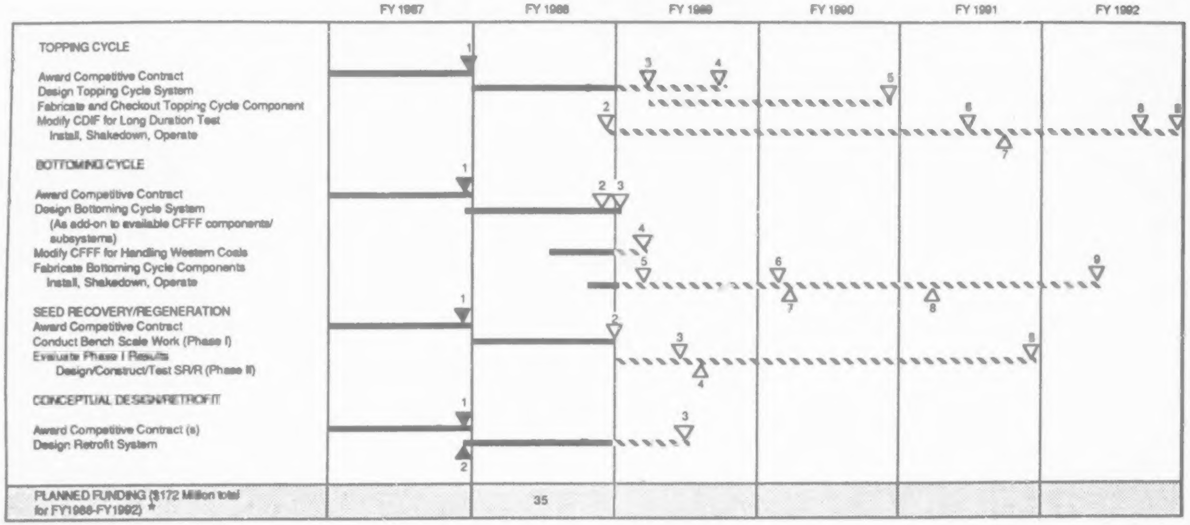
- develop technical and environmental data for the integrated MHD topping cycle system through long-term (1,000 hours) POC testing,
- develop technical and environmental data for the integrated MHD bottoming cycle subsystem through long-term (4,000 hours) POC testing,
- design and construct a seed regeneration system capable of independent operation, using spent seed materials from the MHD process,
- prepare a conceptual design for an MHD retrofit plant, and
- continue system studies and supporting research necessary for system testing.

Results of the topping cycle POC tests at the Component Development and Integration Facility (CDIF), coupled with the bottoming cycle POC test results obtained at the Coal Fired Flow Facility (CFFF), and the seed regeneration POC effort will provide the critical engineering data base for the private sector's final decision on proceeding with the design, construction, and operation of an MHD retrofit. The development schedule, decision points, and resource requirements are shown in Exhibit 3.

The current MHD program is directed toward base-load, both stand-alone and retrofit, coal-fired power plant application. Development of a base-load utility plant should enhance development of MHD for other utility and industrial applications. MHD may also find application in the electrical energy intensive industries.

Exhibit 3

MHD Development Schedule



*In constant FY'88 dollars.

TOPPING CYCLE MILESTONES

1. Award Competitive Contract - 9/87
2. Upgrade Coal and Seed Transfer System - 9/88
3. Critical Design Review (CDR) - 1/89
4. Complete Design Prototype Hardware - 7/89
5. Ship Prototype Hardware to CDIF - 9/90
6. Prototype Hardware Installed at CDIF - 3/91
7. Initiate Long Duration Testing at CDIF - 7/91
8. Complete Long Duration Testing at CDIF - 6/92
9. Topping Cycle Contract Complete - 9/92

BOTTOMING CYCLE MILESTONES

1. Award Competitive Contract - 9/87
2. Critical Design Review (CDR) Add on Components - 9/88
3. Bottoming Systems Design Complete - 10/88
4. Modification of CFFF to Handle Western Coal Complete - 1/89
5. Bottoming Systems Components Fabricated/Installed - 1/89
6. Bottoming Cycle Shakedown/Acceptance - 11/89
7. Commence Western Coal Studies - 12/89
8. Initiate Trace Element Studies - 12/90
9. Complete Bottoming Cycle Testing - 3/92

SEED RECOVERY/REGENERATION MILESTONES

1. Award Competitive Contracts - 9/87
2. Complete Phase I (Bench-Scale) - 10/88
3. Select Phase II Contractor - 4/89
4. Commence Phase II of SR/R Effort - 5/89
5. Phase II SR/R Contract Complete - 9/91

RETROFIT CONCEPTUAL DESIGN MILESTONES

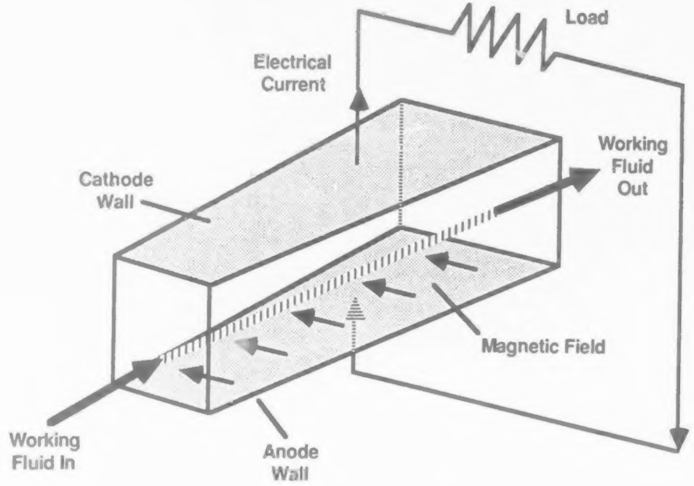
1. Award Conceptual Design Contract - 9/87
2. Begin Conceptual Design - 9/87
3. Conceptual Design Complete - 3/89

Active programs are underway in the U.S.S.R., China, Japan, Poland, Italy, India and other countries. Some countries have chosen to demonstrate gas-fired MHD systems before pursuing coal-fired MHD systems that have additional technical barriers. The U.S.S.R. believes its MHD engineering design base is sufficient for it to proceed with the design and construction of the world's first gas-fired commercial MHD plant, at a scale of about 500 MWe.

As part of the MHD program, international activities of several nations are monitored and evaluated through contact with the international MHD scientific and technical community. Opportunities are continually sought for leveraging public R&D funds and reducing the Nation's financial and technical risks.

Exhibit 4

Principle of MHD


Load
Electrical
Current
Working
Fluid
Out
Cathode
Wall
Magnetic Field
Working
Fluid In
Anode
Wall

- Flow of Electrically Conductive Fluid (Gas or Liquid) Through a Magnetic Field
- Electric Potential is Developed Perpendicular to Both Fluid Flow and Magnetic Field

I

Overview of Magnetohydrodynamics

Interest in MHD is evident as early as the nineteenth century. Scientists such as Michael Faraday (1791-1867) experimented with the generation of electricity by moving an electrical conductor through a stationary magnetic field. In the years 1920-1950, interest in MHD was kindled through theoretical work on cosmic problems and projects for the thermonuclear generation of energy. Beginning in 1960, spacecraft began to provide evidence of MHD phenomena from plasma winds blowing continuously out from the sun. Since then, interest in MHD has continued to grow, and its potential applications in different fields, such as geophysics, power generation, and military uses, has initiated an era of sustained research and development in MHD technology.

The MHD generator is based on the concept of using flowing ionized gases or liquid metals, which have been heated by chemical or nuclear fuel, as the moving conductor in an electric generator. By using the working fluid directly, the MHD generator removes the intermediate steps of generating steam and turning a turbine. And MHD can utilize working fluids at higher temperatures than conventional powerplants. This higher temperature leads to increased conversion efficiencies.

The simplest MHD generator geometry is a linear geometry in which the gas flows through a linear duct or channel. The magnetic field is at right angles to the gas-flow velocity, which induces a Faraday electric field at right angles to both the flow velocity and magnetic fields (see Exhibit 4). If electrodes are placed on either side of the channel and connected through an electrical load or resistance, current will flow through the gas, electrodes, and load. Because the gases leaving the MHD channel are still at a relatively high temperature (typically 3700°F), the exhaust heat can be recovered and used to generate steam to produce additional electricity, or provide process heat. A schematic of a representative MHD system component arrangement is shown in Exhibit 5.

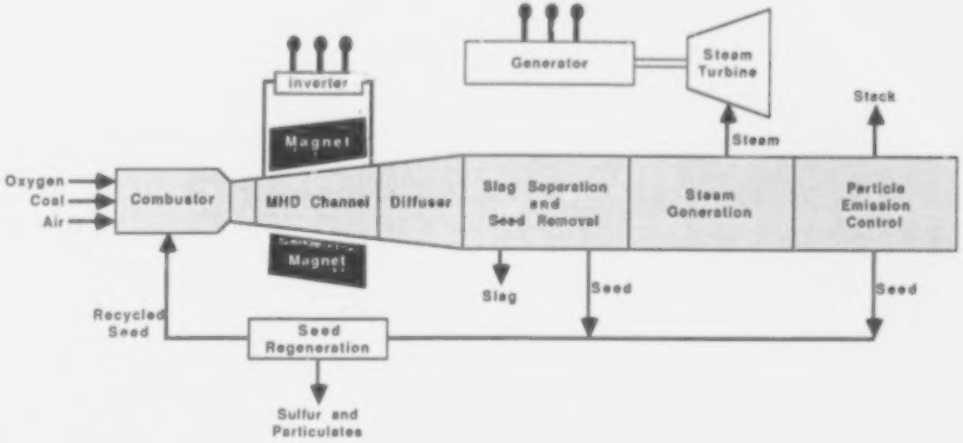
MHD power plants are projected to be able to convert coal-derived heat directly to electricity with potential coal-pile to busbar plan efficiencies in the 50-60 percent range. The first market entry systems are likely to have efficiencies in the low to mid-forty percent range. Existing coal-fired power plants operate with plant efficiencies in the 32-35 percent range. Near term, advanced, coal-fired technologies presently under development are projected to have efficiencies in the high 30 to low 40 percent range.

In addition to improved thermodynamic efficiency, MHD as well as some of the other advanced coal fired technologies can offer environmental benefits such as greatly reducing the emissions of SO_2, NO_x, CO_2 and particulates. The potassium seed material used to ionize the MHD combustion gases reacts with oxides of sulfur to reduce SO_2 emissions. Thus an important attribute of open-cycle MHD power generation is its self-contained sulfur removal system. The combustion control process minimizes formation of NO_x.

Although the major emphasis of MHD power systems development has historically been focused on utility sector applications, MHD can also be potentially applied to other energy sectors. In addition, interest in potential military applications of MHD has historically been focused in the Soviet Union where explosive MHD technology appears to be well advanced. The Soviets have characterized the energy potential of explosive MHD technology as being in pulses ranging from 10-100 microseconds and up to hundreds of gigawatts of power. In the United States, there appears to be military interest in MHD power systems for potential steady-state power production and burst power applications.

Exhibit 5

Typical Open Cycle MHD System Component Arrangement


Oxygen
Coal
Air
Combustor
Recycled Seed
Inverter
Magnet
MHD Channel
Magnet
Diffuser
Seed Regeneration
Sulfur and Particulates
Slag Separation and Seed Removal
Slag
Seed
Generator
Steam Turbine
Steam
Steam Generation
Stack
Particle Emission Control
Seed

The MHD program has produced scientific and technical results which have found applications in other energy and non-energy technologies. For example, MHD combustor development work has found its way into advanced combustors for application in industrial and utility boilers and non-intrusive diagnostic instrumentation has found application in other energy systems. Furthermore, the general science of high temperature, erosion- and corrosion-resistant materials has been significantly advanced as a result of the MHD program.

II

Technology Status

MHD research has yielded major advances in component and system performance. This chapter provides a component by component description of the MHD system, the required component performance levels, and the current status of each component.

Integrated MHD Topping Cycle

The function of the MHD topping cycle is to produce electrical power directly from the high temperature, high pressure, electrically conductive gases produced in a coal-fired combustor. Conductivity of the high pressure, high temperature (4600°F to 4800°F), combustion gases is increased by addition of a potassium salt (the "seed"). In current applications, the gases from the combustor are accelerated through a nozzle and then passed through a channel which is located within a magnetic field. The movement of the electrically conductive gases through the magnetic field produces DC electric power. DC to AC conversion is accomplished by means of an inverter system. The seven components or subsystems making up the topping cycle are described below along with their current status.

Combustor

The coal combustor is the starting point of the MHD power generation system. It is the function of the combustor to efficiently convert the coal and oxidizer into a uniform high temperature plasma. Efficiency of the entire power plant is affected by the performance of the coal combustor.

Performance Requirements - Combustor durability of a minimum of 10,000 hours is required at a pressure of 5-6 atmospheres. Electrical conductivity should be no less than 6 mhos/meter with a heat loss within a range of 3-5 percent at 500 MW_t. Both pressure and heat losses must be low and combustion efficiency high. The combustor must achieve uniform combustion, delivering a high temperature, high pressure, electrically conducting plasma with uniform spatial distribution. Wall surfaces exposed to combustion gases must be designed to be slag covered. Long duration coal combustor performance must be demonstrated with an integrated power train at 50 MW_t in order to confirm scaling to a 250 to 300 MW_t combustor size. The long duration testing of a combustor in an integrated MHD topping cycle and a thorough evaluation of the resulting data are the principal objectives of the topping cycle proof-of-concept tests conducted at the Component Development and Integration Facility (CDIF) in Butte, Montana.

Current Status - Combustor testing began with short duration (approximately two hour) coal-fired tests and will gradually increase to long duration tests culminating in 1000-2000 hours of testing of prototypical hardware. No major life limiting phenomena were observed after several hundred hours of testing combustors at 20 MW_t scale with pressures of 5-6 atmospheres and conductivity of 6 mho/meter. Heat loss of 10 percent at 20 MW_t is expected to scale to 3-5 percent at 250 to 300 MW_t. Areas that need further study are scaling of combustor geometry with thermal output, electrical isolation, slag rejection and seed loss, and material integrity.

Nozzle

The nozzle in an MHD power plant acts as a transition piece that accelerates the flow of the products of combustion from the combustor to the channel. The flow at the exit of the nozzle is usually near sonic or supersonic.

Performance Requirements - The nozzle must produce efficient acceleration throughout with minimum heat losses through the walls and minimum pressure losses due to friction. Materials to withstand thermal stresses, an efficient cooling system, and electrical isolation of the cooling system also must be provided to meet the performance requirements of the nozzle.

Current Status - Aerodynamic design of the nozzle and its construction can be considered current technology. Only if the nozzle extends into the fringe field of the magnet so that gases within the nozzle would experience magnetic interaction would further nozzle design be required.

Channel

The MHD channel converts the thermal and kinetic energy of the seeded, coal combustion products directly into electricity. The overall performance of the MHD system depends strongly on the level of the MHD channel performance.

Performance Requirements - The requirements are concerned with open-cycle linear channels configured in a segmented (Faraday) or diagonal mode. The channel component development can be considered a major technical issue requiring additional research to validate scale-up, long term performance, durability, and operation (loading and control). Development of MHD channels will continue, with efforts focused on the design and construction of a new channel tailored to a specific magnet and capable of sustained operation for a minimum of 1000 hours (proof-of-concept tests).

Current Status - A significant base of analytical and experimental data concerning the power generation capabilities of MHD channels has been developed. Demonstration of about 12 percent enthalpy extraction was successfully achieved (as predicted) using a toluene-fired combustor at

300 MW_t scale. Currently, the two major channel development and testing centers in the U.S. are the Component Development and Integration Facility (CDIF) in Butte, Montana and the Avco Everett Research Laboratory in Everett, Massachusetts. Platinum-clad and stainless-steel-clad copper anodes accumulated 1300 power hours in durability tests at Avco. Extrapolation of electrode attrition rate data indicates a life time of up to 9000 hours may be attainable in commercial application. Performance targets were met with simulated coal operation at a scale of 20MW_t. Channel operation with a coal-fired combustor is presently being investigated at the 50 MW_t scale to resolve differences between observed and predicted power generation results. Acquisition of an MHD channel meeting proof-of-concept test requirements was initiated in FY 1987.

Superconducting Magnet

Power generated in the MHD cycle is a result of a charged flow passing through a magnetic field. Because intense magnetic fields over large volumes are required to achieve desired MHD plant performance and economic targets, the use of superconducting magnets is necessary.

Performance Requirements - Future magnets may be designed for a peak, on-axis field strength of 6 Tesla (T), although for channels operating at supersonic flow velocities, a lower peak field of 4.5 T is adequate. Magnet size, design, and performance are determined by the requirements of the MHD channel which resides in the interior bore of the magnet.

Current Status - Large magnet systems have been constructed to satisfy the needs of the fusion energy program. Many, but not all, of the constituents required in the construction and operation of a large superconducting magnet for MHD power plants are now, or with some extrapolation, within the current state-of-the-art. The major need is to optimize the engineering design in order to make construction feasible, and the overall size consistent with operational safety and performance in order to hold costs to an acceptable level. Superconducting magnet research for MHD applications is being accomplished at MIT under a contract to design, develop, and test a niobium-titanium alloy internally cooled cable superconductor (ICCS). A length of this ICCS is being manufactured and will be tested in a configuration representing that to be used in a large retrofit size MHD magnet. This activity, in concert with two superconducting MHD magnets which have already been built and the existing technologies from the high energy physics and the fusion energy programs, will constitute the proof-of-concept for MHD superconducting magnet systems. However, for the integrated topping cycle proof-of-concept testing at the CDIF, it is anticipated that the existing iron-core magnet, which does not contain superconducting materials, will be utilized.

Diffuser

The diffuser links the topping cycle components with the bottoming cycle components in an MHD power plant. There are two principal reasons for attaching a diffuser to the exit of an MHD channel: 1) It increases the power extracted from the channel by allowing the channel exit pressure to be reduced while maintaining a required static pressure at the diffuser exit to the downstream components; and 2) it reduces the velocity of the hot gases from the channel to the downstream components, the radiant boiler section, thus partially converting the kinetic energy into static pressure.

Performance Requirements - The diffuser pressure recovery factor is the ratio of the achievable static pressure rise between the diffuser inlet and exit to the total pressure measured at the diffuser inlet. Performance of diffusers in large power plants cannot be specified with confidence because of limited availability of analytical tools and experimental experience. However, while performance has a limitation of specificity, general requirements include the maximizing of the pressure recovery factor, minimizing heat loss, and reducing exit gas velocity to a level that the radiant boiler wall can tolerate without significant erosion.

Current Status - Diffusers have been designed for MHD channels operating with both subsonic and supersonic flows. Existing analytical models of diffusers have been developed for both flow regimes. In addition, three dimensional analyses of diffuser performance from tests at CDIF have been conducted and will continue to be pursued as part of the integrated topping cycle test effort a CDIF.

Power Control and Conditioning (PC&C) - (Includes Inverter)

The DC output of MHD power must be efficiently inverted into high-quality AC before being placed on a commercial power grid. The DC output of the MHD generator must be consolidated from many electrodes, each operating at a different voltage. The power conditioning system which collects the raw DC power and inverts it into usable AC power must be stable in the presence of both a fluctuating MHD generator output as well as the changing grid conditions.

Performance Requirements - The conversion of large quantities of DC power from the MHD channel for connection to the utility's AC grid requires the consolidation of the DC output from numerous electrodes of an MHD generator. Additionally, current consolidation must also provide for local control of electrode currents for the protection of the channel. These circuits are required for long duration channel testing at CDIF.

Current Status - PC&C research at Avco has led to the development of a new and more efficient circuit using gate turn-off (GTO), solid-state devices. Advanced systems are also being studied at Westinghouse. Analytical efforts are being conducted to study the optimization of channel-loading techniques, leading to enhanced channel performance, improved circuit reliability, and reduced power losses and costs. Long duration testing will be performed at CDIF with additional power conditioning circuits. The inverter portion of the PC&C has been successfully demonstrated at CDIF, and, therefore, no further inverter research is required. The interface between the power conditioning circuitry and the inverter hardware (provided by EPRI) at the CDIF will be evaluated as part of the integrated topping cycle.

Feed Systems

The feed system will consist of crushers and pulverizers required to obtain the specified coal particle size distribution, dryers to reduce moisture, and feed lines to the combustor to ensure a uniform flow of coal into a combustor at several atmospheres of pressure.

Performance Requirements - A mixture of potassium salts must be injected into the combustion gas stream and mixed uniformly prior to the stream's entry into the MHD channel. The mixture must be delivered into the stream at a controlled rate, against a pressure differential of 5-6 atmospheres. For plants requiring oxygen-enriched air, oxygen must be delivered to, or produced at, the plant site, blended with atmospheric air, compressed, preheated and then injected into the pressurized combustor.

Current Status - Commercial feed systems are available and other systems have been under development for DOE, both at CDIF and CFFF, and have been successfully operated. Seed handling is not a major technical problem but the regeneration of spent seed is a major technical issue currently under investigation.

Integrated MHD Bottoming Cycle

The functions of an MHD bottoming cycle are to recover heat energy from the combustion gases after exit from the diffuser; remove and collect coal slag and spent seed/ash from heat recovery/seed recovery units; and control both gas phase and particulate emissions to meet environmental requirements; and also generate electricity from the recovered heat.

Heat is recovered from the combustion gases by radiant and convective boiler sections which: (a) produce steam for electrical power generation in a conventional turbogenerator; and (b) preheat combustion air/oxidizer. Emission levels of NO_x are reduced by tailoring the time-temperature profile within the radiant boiler in a manner which permits decomposition of NO_x to achieve acceptable levels. SO_x is converted to a solid compound by reaction with potassium seed. Spent seed will be separated from the seed/ash mixtures and supplied to a regeneration system where it will be converted to a non-sulfur-containing potassium seed species. Fine (micron-size) particulates are controlled by use of an electrostatic precipitator or a baghouse. The major components or subsystems which comprise the bottoming cycle are described below.

Radiant Furnace

The initial high-temperature heat removal from the coal combustion gases to produce steam is accomplished in the radiant furnace. The furnace also provides for sufficient high-temperature residence time to permit the decomposition reaction of NO_x to elemental nitrogen and oxygen to meet environment requirements.

Performance Requirements - The temperature of the gases at the diffuser outlet is in the range of 3500°F to 4000°F. Appropriate materials that can withstand high heat transfer temperatures over long periods are required. Sufficiently high radiant heat transfer rates are required to achieve high cycle efficiencies. If the MHD powerplant were to be used for peak-load applications, these materials should also be able to withstand intermittent temperature variations.

Current Status - The radiant boiler is a key subsystem component. Testing at a 25-30 MW_t scale has been conducted at the CFFF. Supporting analytical efforts and complementary research have been conducted at Argonne National Laboratory (ANL). By maintaining the stoichiometry at below 0.90 (fuel-rich) for gases entering the radiant boiler, it has been shown that NO_x can be controlled. Data on ash and seed deposits obtained via supporting research have been used to develop models to predict effective heat transfer coefficients and for developing efficient boiler designs.

Secondary Combustor

The combustion of the process gases is completed in the secondary combustor. Subsequently, the coal derived sulfur compounds are converted to SO_x which ultimately reacts with potassium to produce K_2SO_4, thereby achieving levels of SO_x below the allowable limits.

Performance Requirements - Although the secondary combustor is a well-developed component of the combustion system, its application in the MHD bottoming cycle requires some modifications. These modifications are to withstand higher temperatures and to allow for the necessary residence time for combustion completion and sulfide conversion.

Current status - Integrated testing of the bottoming cycle has been conducted at the CFFF at a 25-30 MW_t scale. Injecting and mixing air or recirculated combustion gas into boilers of moderate size is common in commercial practice and represents existing technology.

Steam Superheater, Reheater, and Economizer

These heat transfer components provide steam for process use by convective cooling of the combustion gases.

Performance Requirements - The steam superheater is a key component and its low-temperature application is fairly common. However, in addition to the interaction with corrosive potassium compounds in the MHD powerplant, the steam superheater and reheater tubes will experience metal temperatures of 800°F to 1300°F and fire-side temperatures of 2900°F. Appropriate materials of construction and high heat transfer coefficients are required at these high temperatures. The economizer and low-temperature air/oxidant heaters are well-developed, commonly used power plant items which do not require further development.

Current Status - Integrated testing of the bottoming cycle has been conducted at the CFFF at a 25-30 MW_t scale. The existing data are being extended to include information on materials corrosion and erosion for air-heater and superheater modules at CFFF. The modules are constructed of tubes made of carbon steel, Croloy, and Incoloy. Tests have shown that 300-series stainless steels have low-corrosion rates when exposed to ash/seed mixtures at these temperatures.

Air and Oxidant Heaters

These components collectively produce preheated, oxygen-enriched air for the coal combustor and preheated air for the secondary combustion chamber.

Performance Requirements - The low-temperature heaters have been well-developed. For the high-temperature applications, appropriate materials of construction are required. Air heater metal-tube temperatures may reach 1300°F.

Current Status - Integrated testing of the bottoming cycle has been conducted at the CFFF at a 25-30 MW_t scale. High-temperature air-heater development is a long-term item, essential for the realization of mature MHD power generation systems; however, this component is not needed for early commercial MHD applications. Work on this portion of the effort will be continued as part of the Integrated Bottoming Cycle effort.

Electrostatic Precipitator or Baghouse

Performance Requirements - These components may be used to remove particulates from the gas stream to meet environmental requirements.

Current Status - Particle size distribution and loading in bottoming cycle equipment have been modeled at the CFFF and ANL and verified in experiments at the CFFF. In general, it has been found that the fraction of micron and submicron size particles present in the MHD flue gas stream is greater than that which occurs in conventional coal-fired power systems. For this reason, it is important to measure the efficiency with which electrostatic precipitators (ESP) can capture the fine, low-resistivity, particulate-stream characteristic of the MHD process. The research at the CFFF and the ANL has included investigations of the efficiency of ESP and fabric filters.

Seed Regeneration

Process studies have been conducted for several candidate seed regeneration systems. In this area, the critical technical issues relate primarily to the economics of processing in an environmentally acceptable manner. Additional data that support process economy must be obtained in the areas of reaction kinetics, process yields, energy requirements and equipment costs for a seed recovery/regeneration system.

III

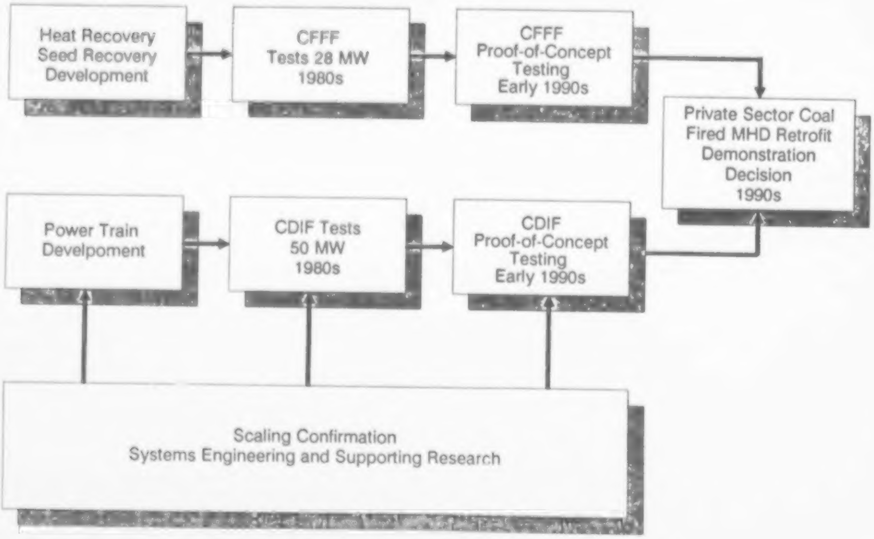
Planned FY 1988 Research and Development

Introduction

The objectives of the R&D component of the program are to establish the performance levels and long-term durability of components and subsystems in an integrated topping cycle and in an integrated bottoming cycle. Other key objectives are to establish the technical performance and economic feasibility of a seed regeneration process, and to conduct a feasibility and conceptual design study of a fully integrated MHD retrofit power plant. These objectives and currently planned efforts to achieve them are reviewed below for each system component. The program approach is shown in Exhibit 6. For FY 1988, the Congress has appropriated $35 million for the POC program, and the program activities in FY 1988 as supported by this funding are described in the following sections.

Exhibit 6

Coal-Fired MHD System Development


Heat Recovery
Seed Recovery
Development
CFFF
Tests 28 MW
1980s
CFFF
Proof-of-Concept
Testing
Early 1990s
Private Sector Coal
Fired MHD Retrofit
Demonstration
Decision
1990s
Power Train
Develpoment
CDIF Tests
50 MW
1980s
CDIF
Proof-of-Concept
Testing
Early 1990s
Scaling Confirmation
Systems Engineering and Supporting Research

Integrated MHD Topping Cycle

The approach to this element of the program is the development, demonstration and integration of the components. Initiated late in fiscal year 1987, the objectives of this effort are to provide for the design, construction, and delivery of all hardware necessary to conduct long-duration, integrated

MHD topping cycle proof-of-concept tests at the CDIF in Butte, Montana. Hardware includes:

- A 50 MW_t coal-fired combustor,
- A 50 MW_t MHD channel,
- An advanced power conditioning/inverter subsystem and all other hardware deemed essential for testing the integrated topping cycle including the nozzle and diffuser.

A contract to accomplish this work was awarded in late fiscal year 1987. Under the 1984 program plan approach proof-of-concept testing would commence in the early 1990s time frame. For the topping cycle program element of the POC, planned activities in FY 1988 include the following:

- Combustor/channel characterization tests at Avco using a 20 MW_t coal-fired combustor, and confirmatory tests at CDIF at the 50 MW_t level.
- Completion and delivery of a coal-fired precombustor and hardware for a continuous slag rejector to the CDIF.
- Upgrade of the coal and seed transfer systems at the CDIF.

Combustor

Two combustor concepts have been pursued in the historical MHD program: one involves rejection of a large portion of the slag; and the other permits 100 percent slag carry-over. DOE has chosen to pursue the slag-rejecting combustion concept. A rugged combustor, capable of extended operation, must be designed and built to commercial standards, and tested.

Channel

When an electric plasma moves through a magnetic-field in a confined space such as a channel, the resulting aerodynamic, magnetic and thermal effects (magnetoaerothermal effects) can combine to cause deleterious effects on channel performance and durability. Since it is believed that there are methods for designing channels to avoid these problems, further investigations will only be conducted to better understand these effects. Several critical parameters have been identified: number of electrodes shorted, electrode pitch to channel height ratio, Hall parameter, electrical loading parameters, gas conductivity profile, electrode width to pitch ratio, iron content of ash and boundary layer thickness. Only the effects of the first two parameters and iron content of the ash have been studied; the remainder will be characterized to complete the analysis. The phenomena of shorting, related to the iron content of the coal ash, will be investigated further. Also, slag-layer development modeling is important to the prediction of electrode voltage drop, boundary layer characteristics and electrode lifetime. Both of these analytical modeling areas are important to the prediction of performance in the CDIF and at larger scales.

Supersonic channel tests will be continued to validate analytical performance models and to obtain data on Hall voltage, electrode current, and sidewall voltage and axial pressure distribution. Research is also required to extend the lifetime of that portion of the insular wall adjacent to the cathode wall. Experimental investigation will also include several engineering approaches to minimize the problems of cathode wall slag polarization and higher electric field in the insular wall producing current leakage, and the subsequent electrochemical corrosion of metallic elements.

Along with the experimental work, engineering design studies will be directed toward improved external packaging of the channel in order to better utilize the magnet warm bore volume. These project results will support the integrated topping cycle tests at CDIF. Future long-duration tests will require the design and construction of a new channel capable of sustained operation of up to 1000 hours of proof-of-concept testing.

Power Conditioning Circuits and Inverters

As previously indicated, power conditioning research (supported by EPRI) has led to the development of new and more efficient circuits using gate-turnoff (GTO), solid-state devices. Additional tests will be directed toward improved circuit reliability and efficiency. An analytical effort will be conducted to study optimization of channel-loading techniques, leading to enhanced channel performance, improved circuit reliability and reduced costs. Additional efforts, to be conducted under the integrated MHD topping cycle, will enable power conditioning system design modification to be performed at the CDIF before long duration testing. To meet these testing requirements at the CDIF, additional power conditioning circuits must be built and installed. No further inverter research is planned, however, the power conditioning/inverter hardware at the CDIF will be evaluated.

Magnet

Magnet research for MHD applications is being pursued specifically to test the niobium-titanium alloy ICCS (Internally Cooled Cable Superconductor). A length of this ICCS will be tested in a configuration closely representing that which would be used in a large retrofit size MHD magnet.

Integrated MHD Bottoming Cycle

The integrated MHD bottoming cycle activities at the CFFF will focus on the completion of the proof-of-concept test program designed to establish a data base for the performance and durability of critical downstream components.

At the end of FY 1987, a contract was awarded for design, engineering, procurement and installation of bottoming cycle components at the CFFF facility, in the areas of:

- coal pulverizing equipment to allow for the processing of both Eastern and Western coals
- installation of an automatic system for transporting spent seed/ash from superheaters, air heater, ESP and baghouse to facilitate long-duration proof-of-concept testing
- design of an intermediate temperature air heater to replace the vitiation heater

The POC tests involve a vitiation heater to preheat combustion oxidant and automatic transport of the solids produced by seed and coal combustion. Emphasis is placed on controlling particulate emissions and to develop data on: ash/seed deposits, material durability, and efficiency of electrostatic precipitation. Additional work at CFFF includes preparation for testing subbituminous western coal and facility modifications necessary to achieve extended test capabilities. For the bottoming cycle program element of the POC, activities in FY 1988 include completing the preliminary design of the integrated bottoming cycle hardware for the CFFF and running duration tests of the bottoming cycle hardware with Eastern coal in the CFFF.

Seed Recovery/Regeneration Process

Initiated in fiscal year 1987, the project in seed recovery/regeneration process involves the development of several candidate processes that will then be evaluated. The most promising process could then be scheduled for subsequent proof-of-concept testing on a plant scale. Bench-scale experimentation in support of design, fabrication and operation of a proof-of-concept seed regeneration plant was implemented in late 1987 and is expected to be completed in 1988. The objective is to demonstrate that potassium sulfate can be regenerated to potassium carbonate or another sulfur-free potassium salt. Processing targets include:

- recovery and recycle of 90 percent or more of the spent potassium seed;
- a plant operating efficiency necessary for minimal impact on the inherent economic advantage of the overall MHD process; and
- plant operations in an environmentally acceptable manner.

Collected samples of slag and ash/spent seed mixtures run at CFFF from coals similar to that burned at CFFF and CDIF will be used for evaluation of seed regeneration processes, and one process could be selected for pilot-plant operation for proof-of-concept regeneration testing. The regenerated seed could then be run in varying mixtures with fresh seed to investigate the effects on topping cycle performance. For the seed recovery/regeneration program element of the POC, planned activities in FY 1988 include the completion of development tests of the candidate seed recovery/regeneration processes.

System Engineering, Supporting Research, and Retrofit Activities

Several contractors will support and complement the proof-of-concept activities by providing for diagnostic instrumentation, basic and environmental research, and general technical support.

The activity associated with the effort to design an MHD retrofit is to conduct a feasibility study/conceptual design of such a system. In late FY 1987, contracts were awarded to prepare conceptual designs of a coal-fired MHD retrofit. Updates of these designs would continue, as needed, based on the results of the topping and bottoming cycles POC efforts. For the activities associated with this portion of the POC program, planned activities in FY 1988 include defining the design requirements, hardware description and design conditions for the MHD retrofit conceptual designs, and the development of diagnostics and instrumentation.

System Integration

The long duration testing of an integrated MHD topping cycle and thorough evaluation of the resulting data are the principal objectives of the topping cycle proof-of-concept tests conducted at the CDIF. The testing began with short (approximately two hours) coal-fired tests, and will gradually increase to long duration tests accumulating a minimum of 1000 hours of durability data using prototypical hardware.

At the CFFF, long duration testing of MHD bottoming cycle components (for heat recovery, seed recovery, and emission control) is a major objective. Integrated MHD bottoming cycle activities will focus on the completion of a proof-of-concept test program designed to establish a data base for the performance and durability of critical downstream components. The POC test program will result in 2000 hours durability data with Eastern coal and 2000 hours on Western coal. Testing of the bottoming cycle components has been conducted at the CFFF, and heat and seed recovery systems which have received analytical and small scale research support will move through the testing phase.

The overall MHD system integration effort encompasses all the major elements of the POC program, viz., the Integrated Topping Cycle, Integrated Bottoming Cycle, Seed Recovery/Regeneration process, and MHD Retrofit Conceptual Design. The system integration of the topping cycle with the bottoming cycle and seed recovery/regeneration process is accomplished through the Integrated Topping Cycle contract which was awarded to TRW. This contract specifically mandates the establishment of a Technology Transfer, Integration and Review (TTI&R) Committee. The TTI&R Committee consists of a broad cross-section of personnel representing contractors participating in all the major program element activities, equipment suppliers to the electric utility industry, potential users of MHD technology, EPRI, and other parties cost-sharing in the program. The TTI&R Committee continually reviews all ongoing program activities and relevant technology data, identifying technology "gaps", and recommends approaches for eliminating/minimizing uncertainties and for compiling MHD system information in a manner that will facilitate technology transfer.

All information necessary to perform MHD system integration is provided by the organizations comprising the TTI&R Committee and is effectively integrated by TRW with assistance, on an as-needed basis, by the PETC MHD technical support contractor.

In summary, contracts have been awarded for the seed recovery/regeneration process, the integrated MHD topping cycle, the integrated bottoming cycle, and conceptual designs for an MHD retrofit. The Chicago Operations Office administers MHD contracts for PETC with Argonne National Laboratory, Mississippi State University, University of Tennessee Space Institute and Babcock & Wilcox. The DOE Idaho Operations Office administers the contract with Mountain States Energy for the operation of the CDIF at Butte, Montana. The principal participants are shown in Exhibit 7.

Exhibit 7a

PRINCIPAL PROGRAM PARTICIPANTS

Topping Cycle POC

Prime Contractor	Sub Contractor
Mountain States Energy (CDIF)	
TRW	- Avco/Textron - Westinghouse - MIT - STD

Exhibit 7b

PRINCIPAL PROGRAM PARTICIPANTS

Bottoming Cycle POC

Prime Contractor	Sub Contractor
University of Tennessee Space Institute (CFFF)	
Babcock and Wilcox	- UTSI - Hudson Engineering
Mississippi State University (Instrumentation)	
Argonne National Lab (HRSR)	

Exhibit 7c

PRINCIPAL PROGRAM PARTICIPANTS

Seed Regeneration POC

Prime Contractor	Sub Contractor
Babcock and Wilcox	- UTSI - Hudson Engineering - Westinghouse - Argonne National Lab
University of Tennessee Space Institute	- RCC
TRW	

Exhibit 7d

PRINCIPAL PROGRAM PARTICIPANTS

Retrofit Conceptual Design

Prime Contractor

MHD Development Corporation (Prime Contractor)

Participants: Montana Power Co., MERDI Corp.,MSE, TRW, Avco, UTSI, B&W, Westinghouse, Gen. Dynamics, and Hudson Engineering

Westinghouse (Prime Contractor)

Participants: Southern Company Services, Gulf Power, UTSI, STD, SEITEC, HMJ

IV

International Activities

A host of countries are involved in the research and development of several aspects of MHD technology to varying degrees. They include Australia, China, Czechoslovakia, Finland, France, India, Israel, Italy, Japan, the Netherlands, Poland, Rumania, U.S.S.R., and Yugoslavia. Australia has been working on open-cycle coal-fired MHD systems based on both linear and disk generator geometries. China has pursued primarily oil-fired MHD, but more recently is involved in coal-fired systems. Czechoslovakia has focused on modeling techniques for evaluating the MHD seed-coal combustion products, while Finland has pursued R&D on MHD generator materials and superconductors for MHD magnets. France and Israel have each been working on liquid metal MHD systems. India has continued a sizable program in MHD technology including a 5 MWt MHD pilot plant based on coal-derived fuels. Italy's focus has been on closed-cycle systems, but more recently it has been studying designs of MHD retrofits to gas and coal-fired steam plants. In Japan, a broad base technology program has been conducted primarily on the university level, although there is current involvement by major industrial and government entities such as the Agency for Industrial Science and Technology and the Ministry of International Trade and Industry. In the Netherlands, closed-cycle MHD R&D is carried out at the Eindhoven University of Technology. In Poland, past efforts have been on the design and development of MHD coal combustors, but currently the MHD effort has been limited to studies at the university level. Rumania, on the other hand, is pursuing a relatively ambitious program based on gas-fired MHD with eventual emphasis on solid fuels (lignites). The U.S.S.R. has a sizable MHD program which includes the operation of a 250 MWt gas-fired MHD pilot plant and the ongoing construction of a 500 MWe commercial power plant near Moscow scheduled for overall plant start-up in the early 1990s. Lastly, Yugoslavia has been involved in dynamic modeling analysis and MHD retrofit plant designs.